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New Perspectives on Pleistocene Biochronology and Biotic Change in the East-Central Great Basin: An Examination of the Vertebrate Fauna from Cathedral Cave, Nevada

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New Perspectives on Pleistocene Biochronology and Biotic Change in the East-Central Great Basin: An Examination of the Vertebrate Fauna from Cathedral Cave, Nevada

by

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Dedication

This dissertation is dedicated to Renata, William, and Kiera.

Waŋná lustáŋ hwo?

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ABSTRACT: The interaction between climate, environments, and mammalian faunas during the late Pleistocene-Holocene has been studied intently over the last several decades. Cave deposits play an important role in our understanding of these complex interactions, but they are especially significant for our understanding of the faunal history of the Great Basin. In order to develop a deeper time perspective on mammalian faunal change, I began a project that integrated several elements necessary for identifying and interpreting biotic change in the Great Basin of the western United States. These elements included development of a framework for understanding the importance of cave deposits for the paleontological record, collection of a mammalian fauna that pre-dates the terminal Pleistocene, identification of that fauna in the midst of shifting taxonomic paradigms, and evaluation of the fauna in the context of previous regional biogeographic models.

I utilized data from the FAUNMAP database to evaluate the significance of the contribution that cave deposits make to the Pleistocene mammal record. Caves do provide unique faunal data in addition to contributing a high percentage of the individual species records for late Pleistocene mammals.

Fieldwork was conducted at Cathedral Cave, NV, in order to assess a fauna that was thought to predate the late Pleistocene-Holocene transition. In excess of 30,000 identifiable fossils were recovered in an excavation area that was roughly 1.5 x 2 x 0.7 m. Prior to fieldwork in 2003, age estimates for the fauna were between 750 ka to 850 ka. New chronologic analyses suggest a more recent age (≤146.02±2.584 ka to 151.2±4.4 ka) that extends the known chronologic distributions of several taxa and alters previously established biochronologic frameworks for the Pleistocene. This work also calls into question previous age assignments for portions of Smith Creek Cave.

Individual faunal identifications were made using a conservative data-reliant approach in order to minimize geographic assumptions and render an independent data set useful for broad biogeographic analyses. Although the faunal data presented here do not explicitly support or refute regional biogeographic models, they do indicate that patterns of faunal change can be found even when species-level identification are not achieved.

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INTRODUCTION

Within the Great Basin of the western United States, research on cave deposits provides the primary basis for our understanding of the effects of Quaternary environmental fluctuations on local plant and animal communities (e.g., Heaton, 1985; Thompson, 1990; Grayson, 1993; Hockett, 2000). Most of these studies were conducted in conjunction with attempts to recover archaeological remains and therefore are focused on the last 30,000 years of geologic time. In general, Pleistocene faunas from the Great Basin remain relatively understudied when compared to other regions of the western United States, probably because of a lack of focused research in the region and difficulties associated with the accurate dating of Great Basin deposits (Grayson, 1993). As such, new paleontological data from sites within the Great Basin significantly increase our understanding of long-term faunal change in the region. Here I review previous Pleistocene faunal records from the east-central Great Basin and summarize new fieldwork conducted at Cathedral Cave, Nevada, within the context of these records. In this chapter I discuss excavation, screening, and sorting methods. I also summarize the results of efforts to evaluate the stratigraphy of the excavation, and provide a preliminary faunal list. More detailed analyses presented in subsequent chapters focus on the general importance of cave deposits, arvicoline rodents and site chronologies at Cathedral Cave

and nearby Smith Creek Cave, detailed descriptions of specific taxonomic groups from the Cathedral Cave fauna, and the importance of methodological approaches to specimen identification for evaluation of biogeographic patterns in the Great Basin.

GEOLOGIC SETTING

Cathedral Cave (CC) is located within Cambrian System limestone at the mouth of Smith Creek Canyon, northern Snake Range, Nevada (Hose and Blake, 1976; Fig. 1a, b). The cave is small, with north-facing entrances and only three major rooms (Fig. 2). The elevation of the cave is approximately 1950 meters, which places it significantly lower than the highest portions of the northern Snake Range (Mount Moriah - 3673 m), but slightly above the Snake Valley to the east (below 1700 m). Active speleogenesis was occurring at the site as recently as June, 2003.

Glacial deposits previously were recognized in both the northern and southern portions of the Snake Range (Birnie, 1985; Osborn and Bevis, 2001), and the upper reaches of Smith Creek Canyon contained montane glaciers during the late Pleistocene (Thompson, 1979). However, there is no current evidence that suggests that these glaciers extended down canyon to the position of Cathedral Cave. Thrust faulting is present in Smith Creek Canyon but not in the lower reaches where CC is situated (plate 1 of Hose and Blake, 1976). This suggests that the development of the lower Smith Creek valley below CC resulted from depositional and erosional processes associated with downcutting by Smith Creek.

GEOGRAPHIC SETTING

Cathedral Cave is geographically situated within the Great Basin, a provincial region that varies in area depending upon the criteria used to define it (Grayson, 1993; Fig. 3). At least four definitions (physiographic, hydrographic, floral, and ethnographic) of the Great Basin are in use (Grayson, 1993). Cathedral Cave is located in the east-central portion of the Great Basin regardless of which definition is utilized.

The Great Basin is characterized by internal drainage and the presence of a series of northeast-southwest trending mountain ranges (horsts) and intervening valleys (grabens; Morris and Stubben, 1994). This physiographic character, coupled with fluctuations in climate, resulted in complex hydrologic and biotic histories for the Pleistocene of the Great Basin (Hershler et al., 2002). Records of the development and drainage of vast internal lakes are known in varying detail from the late Pliocene to Recent (e.g., Oviatt et al., 1992; Oviatt, 1997; Negrini, 2002; Reheis et al., 2002).

The material record of Pleistocene biotic changes in the region varies. In some instances there are biotic records that pre-date the terminal Pleistocene (e.g., Davis 2002; Wigand and Rhode, 2002), but the majority of available data on biotas of the Great Basin are limited to the latest Pleistocene-Holocene. For instance, the history of mammals in the region is known in considerable detail for the terminal Pleistocene-Holocene but is mostly unknown for earlier portions of the Pleistocene (Grayson, 1993, 2006). Although this may reflect the nature of the geologic record, the emphasis on archeological sites in the region likely contributed a certain degree of bias to our understanding of the Quaternary vertebrate record in the region.

QUATERNARY VERTEBRATE PALEONTOLOGY IN THE EAST-CENTRAL GREAT BASIN

Because there are already several excellent reviews that broadly address the Quaternary vertebrate history of the Great Basin as a whole (Grayson, 1982, 1987, 1993, 2000a, 2006; Heaton, 1990), I chose to limit the introductory portions of this study to vertebrate localities in close proximity to Cathedral Cave. For comparative purposes, the background data presented here are limited to localities in the Snake Range and valleys to the east and west (i.e., Snake Valley and Spring Valley). While this is in part a matter of convenience, the history of mammal populations in the Snake Range appears unique with respect to other portions of the Great Basin (Grayson, 2006).

Quaternary vertebrate-bearing localities in the region include Amy's Rock Shelter (Miller, 1979); Cathedral Cave (Bell, 1990, 1995; Bell and Barnosky, 2000; Mead et al., 1992; Owen et al., 2000), Council Hall Cave (Miller, 1979), Crystal Ball Cave (Heaton, 1985), Kachina Cave (Miller, 1979), Lehman Caves (Ziegler, 1964), Owl Cave 1 (Turnmire, 1987), Owl Cave 2 (Turnmire, 1985, 1987), Smith Creek Cave (Howard, 1935, 1952; Stock, 1936; Brattstrom, 1958, 1976; Goodrich, 1965; Bryan, 1979; Miller, 1979; Mead et al., 1982, 1992; Thompson, 1985; Bell and Mead, 1998), and Snake Creek Burial Cave (Barker and Best, 1976; Mead and Mead, 1985; Heaton, 1987; Mead and Mead, 1989; Bell and Mead, 1998; Osterhaudt, 1999; Palevich, 2005). Additional vertebrates were collected from a series of packrat middens in Smith Creek Canyon (Mead et al., 1982). Fecal pellets of pika (*Ochotona princeps*) are known from packrat middens collected in the Snake Valley (Thompson and Mead, 1982).

A modified, regional faunal summary based on the reports listed above is presented in Table 1. Aspects of these summary data emphasize the importance of detailed descriptions of excavation and identification methods. First, the older localities (e.g., Cathedral Cave, Crystal Ball Cave) appear to have more diverse and species-rich assemblages than the younger localities. Second, the level of taxonomic identification varies within taxonomic groups (e.g., Sciuridae) and from locality to locality. Differences in diversity and species-richness potentially represent a 'real' pattern of faunal change in the region, but such an interpretation requires comparable methods of data collection and interpretation (e.g., identification criteria) from individual sites. Variability in taxonomic identifications likely results from a complex combination of recovered elements, the expertise of individual researchers with specific taxonomic groups, and the application of geographic inferences in the identification process. Ultimately, there is value in describing the methodological and philosophical processes that lead to broad interpretations such as decreasing species richness over a geographic region. Data sets built on different philosophical and methodological criteria may not be appropriate for comparison in broad-scale faunal analyses. The processes that lead to taxonomic identification are as much a part of the primary data as the identifications themselves, and should help frame how broader natural history patterns (i.e., biogeography) may be most accurately evaluated (see further discussion in chapter 7).

PREVIOUS RESEARCH AT CATHEDRAL CAVE

Initial fieldwork at CC was conducted by researchers from the Quaternary Studies Program at Northern Arizona University (Bell, 1990). Early studies focused on the

collection and analysis of over 10,000 identifiable mammal fossils excavated from two adjacent test pits (CC 89-1 and CC 89-2) near the back of the cave (Bell, 1990, 1995; Mead et al., 1992; Fig. 4A). Sediments were removed in arbitrary, 10-cm levels, although some deviations were noted (e.g., Level 6 of CC 89-2 encompassed 25 cm; Bell, 1990). Excavated sediments were screened through 6-mm and 1-mm mesh nested screens (Bell, 1990).

Independent uranium-series dates of an ungulate leg bone fragment and overlying flowstone fragment produced ages of 24,400 ± 2000 B.P. and 15,000 ± 200 B.P., respectively (Mead et al., 1992). These ages compared favorably with radiocarbon ages at Smith Creek Cave (Bryan, 1979), situated directly across the canyon, and they suggested that the sediments that produced the mammalian fauna were relatively undisturbed, with little-to-no mixing of chronological units.

Subsequent re-evaluation of the arvicoline rodents from CC suggested that the fauna was considerably older than indicated by the initial U-series age assignment (Bell, 1995; Bell and Barnosky, 2000). The arvicoline rodent assemblage was essentially identical to that from level 4 of the Pit locality in Porcupine Cave, Colorado (Bell and Barnosky, 2000; Bell et al., 2004a; Table 2). The age of arvicolines from level 4 of the Pit locality was estimated to be between 750,000 to 850,000 years on the basis of underlying paleomagnetic data and the known temporal ranges, as they were then understood, of recovered arvicolines (Bell and Barnosky, 2000, Bell et al., 2004a). Based on the similarity of the arvicoline assemblages, CC was considered to be a temporal equivalent to level 4 of the Pit locality (Bell, 1995; Bell and Barnosky, 2000; Bell et al., 2004a).

Given either age scenario, the Cathedral Cave fauna is important. If the younger age estimate is accurate, then CC preserves a unique late Pleistocene fauna unlike any other in North America. If the older estimate is correct, then CC preserves the first diverse assemblage of middle Pleistocene mammals known from the Great Basin. With this recognition, new field efforts were initiated at CC in the summer of 2003 with the intent of resolving the uncertain age, particularly because other research questions were dependent upon achieving resolution of the conflicting chronological data.

FIELD METHODS FOR THE 2003 EXCAVATION

The initial plan for the 2003 excavation was to uncover the backfilled 1989 test pits, attempt to excavate below the maximum depth of the 1989 excavation, and excavate new areas directly adjacent to the 1989 excavation units. Upon arrival at CC, it was obvious that the old test units had been significantly disturbed by human and rodent activity and the initial excavation plan was altered to exclude further excavation near the 1989 test pits.

A new grid system was established using the same rock datum utilized by Bell (1990; Figs. 2, 4A, B). The new grid system consisted of six 1x1 m squares where the western-most squares overlapped the 1989 excavation squares. Stake position was oriented using a Brunton compass with declination set at 0º. Distances and depths relative to datum were determined with a metric tape measure, line, levels, and plumb bobs. All distances were measured using a leveled line. Each square was named in reference to the position of the NE corner stake. Staked areas along the edge of the grid were not excavated.

The (0,0) stake was positioned 28 centimeters below datum (cmbd), 217 cm from the datum at an angle of 145º. The remaining stakes were placed relative to (0, 0) along N-S and E-W axes. To facilitate reconstruction of the grid in the future, the distance from the datum, the depth of each stake relative to datum, and the distance of each stake from another landmark (a stalagmite) were recorded (Table 3).

The area of the 2003 excavation included the eastern halves of squares 1N 2E and 1N 3E and the full squares 1N 3E and 2N 3E, for a total excavated area of approximately 1.5 x 2 m. For most of the excavation, sediment was removed by hand trowel in 5-cm increments except where natural sedimentary levels could be discerned. The finer, 5-cm increments improved the possibility of identifying changes in local faunal assemblages through time relative to the coarser 10-cm increments for previous fieldwork at CC. During the excavation three samples of *in situ* flowstone were collected for radioisotopic analyses (see Chapter 3). The excavation proceeded to depths where the presence of large roof spall or flowstone inhibited further sampling. Based on the sound produced when the roof spall was encountered, these larger blocks of limestone appeared to be sitting directly on the natural floor of the cave. The deepest point of the excavation was 110 cmbd in 2N 3E.

Appendix 1 summarizes the total number of bags (226) of excavated sediment by level. Bags of excavated sediment were labeled according to their grid square of origin and vertical or natural sedimentary level (e.g., 1N 2E 35-40 cmbd; cemented level). Some deviations from this standard include labeled bags of sediment from excavation walls cleaned for profiling (e.g. 'Wall Scrapings'), collapsed wall areas (i.e., 'Wall Collapse'), areas of unreliable provenience (e.g., 'NE Corner "Suspect"), and samples of

flowstone (e.g., ‘Flowstone and Breccia’), and sediments collected from pedasteled rocks with imprecise vertical control (e.g., 87-102 cmbd below pedasteled rocks). One arbitrary level (45-60 cmbd) consists of sediments that sat adjacent to, or beneath, a naturally cemented level.

A series of four generalized cross-sections were made in order to provide perspective of the extent of sedimentary features and to try to identify any features that were unobservable as the excavation proceeded. Cross-sections were drawn for the east wall of grid square 1N 2E, the south wall of grid square 1N 3E, the north wall of grid square 1N 3E, and the north wall of 2N 3E. These areas were chosen for drawing cross-sections because of the presence of stable vertical walls free of larger rocks and/or flowstone. Boundaries between sedimentary features/levels were demarcated with individual markers whose positions were measured relative to the datum (vertical) and corner stakes (horizontal). Samples from each discrete level were collected and evaluated for color differences in ambient light at the cave entrance using a Munsell Color Chart.

All excavated sediments were dry-screened through nested 3.18 mm and 0.7 mm mesh box screens over tarps near the back of Room 2. This process reduced the volume of fine sediments that were transported back to the laboratory. Additionally, it provided a ready sediment supply that was used for backfilling the excavation. All screened sediments were bagged and labeled on-site and then transported back to the Vertebrate Paleontology Laboratory of the Texas Memorial Museum at The University of Texas at Austin.

SCREENWASHING AND SORTING METHODS

A total of 226 plastic bags of matrix were brought back to UT-Austin for screenwashing and sorting. Approximately one-half of the bags were 2-gallon size, the other half were one-gallon. Each bag was wet screened through the same nested box screens used for dry sieving. The wet screening process was conducted by gently agitating sediment-filled screens in a horse trough filled with water. Once the majority of fine sediment was filtered out, the concentrate was rinsed using a sprayer/hose attachment. Sediments were allowed to air dry inside the lab, although when humidity was high it was necessary to have fans running in the vicinity of the screens to facilitate drying. After drying, the sediment concentrate was re-bagged according to screen size. Hence, nearly every bag of washed matrix resulted in two bags of concentrate; one coarse bag from the 3.18 mm screen and one fine bag from the 0.7 mm mesh screen.

The initial objective of the sorting process was that all bone from all sediments (coarse and fine) would be sorted. Early in the sorting process all fossil bone was separated out from individual bags of coarse and fine concentrate. After proceeding in this manner for a month, it became apparent that this method was unrealistic if the project was to be completed in a timely manner. The majority of concentrate was, therefore, sorted only for bones or teeth that were potentially identifiable at lower taxonomic levels (i.e., genus or species). For smaller mammals this meant that primarily upper and lower jaws and teeth were separated out. For some larger mammals, identifiable post-cranial remains were separated out. For non-mammals, all material was sorted when recognized. Because one of the primary research questions required the recovery of lower first molars of arvicoline rodents, a strategy evolved to emphasize the sorting of fossils from coarse

concentrate, where I was finding many of these teeth. All bags of coarse concentrate were sorted for fossils, but only a single bag of fine concentrate from each unique grid and level was sorted. Again, this strategy was partially a function of the research objectives and partially a function of time-management. All fossil sorting was conducted under a binocular microscope.

EXCAVATION STRATIGRAPHY

Sediments removed during the excavation at Cathedral Cave consisted mostly of a combination of vertebrate bone and unconsolidated matrix. When viewed in cross-section, the sequence of sediments was relatively homogenous with respect to sedimentary levels (Figs. 5-8). Grain-size of sediments (excluding bone) throughout the excavation was estimated to be fine or smaller, and no notable grain-size changes were observed through the excavated sequence. Four major sedimentary color variations were observed in each of the cross-sections (Figs. 5-8). There were some instances where minor color differences were noted between similar levels of the cross-sections, but these were only evident in cross-section and were not noted during the excavation process. These variations were not deemed significant enough to justify the excavation of uniquely colored levels.

During the excavation, three distinct sedimentary features were observed. A well-cemented layer of matrix and bone was encountered in all four of the excavation grids. Analysis of sediments from the cemented level indicated that nitratine ($NaNO_3$) was the primary cement mineral (Osborne, 2004). This layer occurred between depths of 42 cmbd (cm below datum) and 57 cmbd but was identified and collected as a discrete level

only from grid squares 1N 3E, 2N 2E, and 2N 3E. This layer was not horizontally continuous throughout the entire excavated area and did not extend into the northernmost portions of excavation (Fig. 8). In the northernmost portion of 2N 3E, there were sediments (texture transition of Fig. 8) from 40-46 cmbd that were visually similar to the cemented level. However, when excavated, there was no clear indication that these sediments were cemented. I interpret the texture transition in this area to represent the northernmost tapering of the cemented level. From 46 cmbd to 60 cmbd in the same area, a large amount of plant detritus and rodent dung was encountered that suggested degradation of an old packrat midden. There was no evidence to suggest that the midden-like material was intrusive, and therefore it may simply represent an older feature relative to the cemented level. For other portions of the excavation, sediments occurring below the cemented level were similar to those above in that they were composed primarily of homogenous, unconsolidated matrix. During screenwashing, abundant rodent dung was noted from the uppermost portions of the excavation, indicating that more recent materials might be mixed with the uppermost portions of the excavation above the cemented level.

Another observable stratigraphic feature was the presence of discrete pockets of very fine-grained, powder-like, white sediments that occurred sporadically throughout the excavation at 53 cmbd and below (Figs. 5-8). Where these pockets were present, they occurred below the cemented layer. Subsequent analyses indicated that these were isolated pockets of gypsum (Osborne, 2004).

Several bones encrusted with secondary mineral deposits were encountered during the excavation and laboratory work. These occurred both above, within, and

below the cemented level although how closely they were associated with the cemented level was not noted. However, nitratine was the primary mineral constituent in samples evaluated by Osborne (2004), and suggests contemporaneity with the cemented level.

Caves tend to have complex depositional systems (Sutcliffe, 1970) although the stratigraphy of the 2003 excavation might seem to indicate that Cathedral Cave has a simple depositional history. The presence of woodrat (*Neotoma*) middens throughout Cathedral Cave and degraded midden material in the excavation stratigraphy suggest that the depositional history of the site is more complex than it would appear. Woodrats are notorious accumulators of plant and animal remains, and their collecting activities can have dramatic impacts on fossil accumulations in cave deposits (Emslie, 1988). I acknowledge that some fossil material reported here and in subsequent chapters might represent reworked material introduced as part of a midden collapse/breakdown in 2N 3E. However, the data presented in subsequent chapters seem to indicate that the fauna is relatively homogenous throughout the excavation. The grid area containing evidence of midden breakdown does not appear to preserve unique faunal elements relative to the rest of the excavation. Therefore, while I acknowledge the possibility of reworked material, I found little evidence to suggest that materials indicative of midden breaddwon differed significantly in age from the rest of the deposit.

PRELIMINARY FAUNAL SYNOPSIS

Unlike many other cave deposits in Smith Creek Canyon, Cathedral Cave has no evidence of archeological remains and none were encountered during either the 1989 or 2003 excavation. The 2003 excavation resulted in the recovery of approximately 30,000

new fossil specimens. To date, 4,514 specimens from the 2003 excavation have been formally incorporated into the collections at the Vertebrate Paleontology Laboratory of Texas Memorial Museum under the unique locality number TMM 43693.

In general, the fossils collected from the 2003 excavation were heavily fragmented, and isolated teeth provided the best material for identification purposes. Some larger rodents (e.g., *Marmota* sp.) and medium-sized carnivorans were exceptions because relatively complete dentaries were common. For both large taxa (e.g., bovids) and small taxa (e.g., most rodents and lagomorphs) fossil material was quite fragmentary. The same was true of reptile and amphibian remains. This taphonomic character, combined with variable levels of reliability of individual elements for taxonomic identification, meant that different identification criteria were invoked for different taxonomic groups and/or specimens.

The individual specimens collected and identified for this project constitute the primary data used to address specific, but varied, research questions forming the basis of subsequent chapters. In instances where I describe aspects of the fauna in detail, I attempt to be explicit regarding identification criteria. In some instances (e.g., lagomorphs, woodrats) I took an approach to identification that some may deem too conservative. However, this approach is appropriate because I want to minimize geographic and temporal assumptions in the identification process. The use of these assumptions in the identification process would inhibit reliable evaluations of the biochronologic and biogeographic questions posed for this project.

Fossils collected during the 2003 excavation represent a diverse faunal assemblage that includes gastropods, amphibians, reptiles, birds, and mammals. A

preliminary synopsis of the CC fauna is presented in Table 4. The taxonomic groups dealt with in detail represent those that were deemed most useful for biochronologic (e.g., arvicoline rodents) and biogeographic (e.g., lagomorphs) analyses. These groups receive detailed systematic treatment elsewhere (see Chapters 3, 5, and 6). Other taxa listed in Table 4 were compiled from projects in various stages of completion, and future research will continue to refine the identifications of taxa within these groups. Notable new records for Cathedral Cave include *Aztlanolagus agilis* (Aztlan rabbit), *Brachylagus coloradoensis* (Colorado pygmy rabbit), *Ondatra zibethicus* (muskrat), *Erethizon dorsatum* (porcupine), and *Taxidea taxus* (American badger). The large felid and two turtles also represent new records.

SUMMARY

Fieldwork at Cathedral Cave in 2003 resulted in the recognition that portions of the deposit retain a relatively homogenous sedimentary record. Little variation in sedimentary composition was found within the excavated area. Most importantly, evidence of mixing of sedimentary layers was lacking for most of the excavation; the uppermost portion of the deposit is a possible exception. As such, evaluation of the fauna through the excavated sequence potentially provides evidence of local biotic changes through time.

The 2003 excavation at Cathedral Cave produced ~30,000 new vertebrate fossils and resulted in the identification of at least eight new taxonomic records for the site. The specimens of *Aztlanolagus agilis* and *Brachylagus coloradoensis* represent the first known records in the Great Basin. Cathedral Cave appears to contain a more diverse

fauna than other localities in the region, but additional work on certain taxonomic groups is still needed. Future taxonomic identifications will further supplement the research presented here and in subsequent chapters of this dissertation.

Table 1. Modified faunal lists of fossil mammals of the east-central Great Basin by locality. Localities with the oldest deposits are at the left, with progressively younger localities to the right. Localities are coded by number as follows: 1 = Cathedral Cave; 2 = Crystal Ball Cave; 3 = Smith Creek Cave; 4 = Snake Creek Burial Cave; 5 = Council Hall Cave; 6 = Owl Cave; 7 = Smith Creek Canyon Packrat Middens; 8 = Amy's Rock Shelter; 9 = Kachina Cave; 10 = Owl Cave 1; 11 = Garrison packrat middens. Locally extant mammals = E (based on Hall, 1946; Wilson and Ruff, 1999). Extant records are exclusive of introduced taxa. p = record based on fecal pellets. Taxa designated with a cf. (i.e., *Sorex* cf. *S. palustris*) are reduced to an indeterminate species designation (i.e., *Sorex* sp.). Uncertain identifications above the generic level (e.g., cf. *Reithrodontomys megalotis*) were excluded. Taxonomic issues regarding fossil taxa are addressed individually in footnotes.

Taxon	1	2	3	4	5	6	7	8	9	10	11	E
Sorex vagrans	-	-	-	-	-	-	-	-	-	-	-	x
Sorex palustris	-	-	-	-	-	-	-	-	-	-	-	x
Sorex sp.	x	x	-	-	-	-	-	-	-	x	-	-
Corynorhinus rafinesquii	-	-	-	-	-	-	-	-	-	-	-	x
Eptesicus fuscus	-	-	-	-	-	-	-	-	-	-	-	x
Myotis evotis	-	-	-	-	-	-	-	-	-	-	-	x
Myotis lucifugus	-	-	-	-	-	-	-	-	-	-	-	x
Myotis subulatus	-	-	-	-	-	-	-	-	-	-	-	x
Myotis thysanodes	-	-	-	-	-	-	-	-	-	-	-	x
Myotis volans	-	-	-	-	-	-	-	-	-	-	-	x
Myotis or *Plecotus* sp.	x	x	-	-	-	-	-	-	-	x	-	-
Myotis sp.	-	x	-	-	-	-	-	-	-	-	-	-
Lasionycteris noctivagans	-	-	-	-	-	-	-	-	-	-	-	x
Lasiurus cinereus	-	-	-	-	-	-	-	-	-	-	-	x
Antrozous pallidus	x	x	-	-	-	-	-	-	-	-		x
Antrozous sp.	-	-	x	-	-	-	-	-	-	-	-	-
Ochotona princeps	x	x	x	-	x	x	-	-	-	-	-	-
Ochotona sp.	-	-	x	x	-	-	x	-	-	-	p	-
Brachylagus idahoensis	x	x	-	x	-	x	x	-	-	x	-	x
Sylvilagus audubonii	-	-	-	-	-	-	-	-	-	-	-	x
Sylvilagus nuttallii	-	x	-	x	-	x	-	-	-	-	-	x
Sylvilagus sp.	x	-	x	x	x	x	-	x	x	x	-	-
Lepus americanus	-	-	-	x	-	-	-	-	-	-	-	-
Lepus californicus	-	x	-	x	-	-	-	-	-	x	-	x
Lepus townsendii	-	x	-	x	-	x	-	-	-	-	-	x
Lepus sp.	x	x	x	x	x	x	-	x	x	x	-	-
Tamias (Eutamias) dorsalis[a]	-	x	-	-	-	-	-	-	-	-	-	x
Tamias (Eutamias) minimus[a]	-	x	x	-	-	x	-	-	-	x	-	x
Tamias (Eutamias) quadrivittatus[a]				-		-			-	-	-	x
Tamias (Eutamias) sp.[a]	x	-	x	-	x	-	-	-	x	-	-	-
Marmota flaviventris	-	x	x	-	x	-	-	x	-	-	-	x

Table 1 continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	E
Marmota sp.	x	-	-	-	-	x	-	-	-	-	-	-
Ammospermophilus leucurus	-	-	x	-	-	-	x	-	-	x	-	x
Ammospermophilus sp.	x	x	-	-	-	-	-	-	-	x	-	-
Spermophilus lateralis	x	-	-	-	-	x	-	-	-	x	-	x
Spermophilus townsendii	-	x	-	-	-	x	-	-	-	x	-	x
Spermophilus variegatus	-	-	-	-	x	-	-	-	-	-	-	x
Spermophilus sp.	x	-	x	-	x	x	x	x	x	x	-	-
Thomomys bottae (= *T. umbrinus*)[b]		x		-		-			-	x	-	x
Thomomys talpoides	x	-	-	-	-	-	-	-	-	-	-	x
Thomomys sp.	x	-	x	-	x	x	-	-	x	x	-	-
Chaeotodipus formosus	-	-	-	-	-	-	-	-	-	-	-	x
Perognathus parvus	-	-	-	-	-	-	-	-	-	x	-	x
Perognathus longimembris	-	-	-	-	-	-	-	-	-	-	-	x
Perognathus sp.	x	x	x	-	x	-	x	-	x	x	-	-
Microdipodops megacephalus	-	x	-	-	-	-	-	-	-	-	-	x
Microdpodops sp.	-	-	x	-	-	-	-	-	-	-	-	-
Dipodomys microps	-	x	-	-	-	-	-	-	-	x	-	x
Dipodomys ordii	-	-	-	-	-	-	-	-	-	-	-	x
Dipodomys sp.	x	-	x	-	-	-	-	-	x	x	-	-
Peromyscus maniculatus	x	x	-	-	-	-	-	-	-	-	-	x
Peromyscus crinitus	x	-	-	-	-	-	-	-	-	-	-	x
Peromyscus truei	x	-	-	-	-	-	-	-	-	-	-	x
Peromyscus sp.	x	x	x	-	x	x	-	-	x	x	-	-
Onychomys leucogaster	x	-	-	-	-	-	-	-	-	-	-	x
Reithrodontomys megalotis	-	-	-	-	-	-	-	-	-	x	-	x
Neotoma lepida	x	x	x	-	x	-	x	x	x	x	-	x
Neotoma cinerea	x	x	x	-	x	x	x	x	x	x	-	x
Neotoma sp.	x	-	-	-	-	x	x	-	-	x	-	-
Allophaiomys pliocaenicus	x	-	-	-	-	-	-	-	-	-	-	-
Phenacomys gryci	x	-	-	-	-	-	-	-	-	-	-	-
Phenacomys sp.	x	-	x		-	-	-	-	-	-	-	-
Microtus meadensis	x	-	-	-	-	-	-	-	-	-	-	-
Microtus paroperarius	x	-	-	-	-	-	-	-	-	-	-	-
Microtus longicaudus	-	-	-	-	-	-	-	-	-	x	-	x
Microtus montanus	-	-	-	-	-	-	-	-	-	-	-	x
Microtus sp.	x	x	x	-	x	x	x	x	x	x	-	-
Mictomys sp. (not *borealis*)	x	-	-	-	-	-	-	-	-	-	-	-
Mimomys sp.	x	-	-	-	-	-	-	-	-	-	-	-
Ondatra zibethicus	-	x	-	-	-	-	-	-	-	-	-	-
Lemmiscus curtatus	x	x	-	-	-	x	-	-	-	x	-	x
Erethizon dorsatum	-	-	x	-	-	-	-	-	-	-	-	x

Table 1 continued.

Taxa	1	2	3	4	5	6	7	8	9	10	11	E
Canis latrans	-	-	-	x	-	x	-	-	-	-	-	x
Canis lupus	-	-	-	x	-	-	-	-	-	-	-	-
Canis sp.	-	x	x	-	x	-	-	x	x	-	-	-
Urocyon cinereoargenteus	x	-	-	x	-	-	-	-	-	-	-	x
Vulpes macrotis	-	-	-	x	-	-	-	-	-	-	-	-
Vulpes vulpes	-	x	x	x	-	-	-	-	-	-	-	x
Vulpes velox	-	x	x	x	-	-	-	-	-	-	-	x
Vulpes sp.	x	-	-	-	-	x	-	-	-	-	-	-
Ursus sp.	-	-	x	-	-	-	-	-	-	-	-	-
Bassariscus astutus	-	-	x	-	-	-	-	-	-	-	-	-
Martes americana	x	x	-	x	-	-	-	-	-	-	-	-
Martes nobilis	x	-	x	x	-	-	-	-	-	-	-	-
Martes sp.	-	-	x	-	-	-	-	-	-	-	-	-
Mustela erminea	-	-	x	-	-	-	-	-	-	x	-	x
Mustela erminea or *M. nivalis*	x	-	-	-	-	-	-	-	-	-	-	-
Mustela frenata	x	-	x	x	-	-	-	-	-	-	-	x
Mustela nigripes	x	-	-	x	-	-	-	-	-	-	-	-
Mustela nivalis	-	-	-	x	-	-	-	-	-	-	-	-
Mustela vison	-	-	x	-	-	-	-	-	-	-	-	-
Mustela sp.	x	x	x	-	-	-	-	-	-	-	-	-
Taxidea taxus	-	-	x	x	-	x	-	x	x	-	-	x
Gulo gulo	-	-	-	x	-	-	-	-	-	-	-	-
Brachyprotoma brevimala	-	x	-	-	-	-	-	-	-	-	-	-
Mephitis mephitis	-	-	-	-	-	-	-	-	-	-	-	x
Spilogale gracilis (*putorius*)[c]	x	-	x	x	-	-	-	-	-	-	-	x
Spilogale sp.	-	-	x	-	-	-	-	-	-	-	-	-
Felis onca	-	-	x	-	-	-	-	-	-	-	-	-
Felis concolor	-	x	x	-	-	x	-	-	-	-	-	x
Lynx rufus	x	-	x	x	-	-	-	x	x	-	-	x
Lynx sp.	-	x	-	-	-	-	-	-	-	-	-	-
Smilodon sp.	-	x	-	-	-	-	-	-	-	-	-	-
Equus sp.	-	x	x	x	-	x	-	-	-	-	-	-
Camelops sp.	-	x	x	x	-	x	-	-	-	-	-	-
Hemiauchenia sp.	-	x	x	-	-	-	-	-	-	-	-	-
Cervus canadaensis				-		-				-		x
Cervus sp.	-	-	x	-	-	-	-	-	-	-	-	-
Odocoileus hemionus	-	x	x	-	-	-	-	-	-	-	-	x
Odocoileus sp.	-	-	-	-	-	-	-	x	-	-	-	-
Antilocapra americana	-	x	x	-	-	x	-	-	x	-	-	x
Bison antiquus	-	-	-	-	-	x	-	-	-	-	-	-
Oreamnos harringtoni	-	-	x	-	-	-	-	-	-	-	-	-
Ovis canadensis	-	x	x	-	x	x	-	x	x	-	-	x
Ovis sp.	-	x	x	-	-	-	-	-	-	-	-	-

Table 1 continued.

[a]In recent taxonomy, the genus *Eutamias* is synonymous with *Tamias* (Wilson and Reeder, 1993; Wilson and Ruff, 1999).

[b]Heaton's (1985) reference to *Thomomys umbrinus* followed Hall (1981) who included *T. bottae* as a synonym of *T. umbrinus*. In more recent taxonomic treatments, *T. bottae* is considered distinct from *T. umbrinus* (Wilson and Reeder, 1993; Wilson and Ruff, 1999).

[c]The western form of the spotted skunk (*Spilogale gracilis*) was once considered synonymous with the eastern form (*S. putorius*). The use of *S. putorius* in some of the records listed above reflects outdated taxonomy.

Table 2. The arvicoline rodent faunas from Cathedral Cave and the Pit Locality, Porcupine Cave, CO. Data for the 1989 excavation from CC and Porcupine Cave are from Bell and Barnosky (2000) and Bell et al. (2004a). The 4-triangle morphotype of *L. curtatus* was listed as *Lemmiscus* sp. in Bell and Barnosky (2000) but was more recently treated as *L. curtatus* by Barnosky and Bell (2003). x = present; - = absent. 4T = 4-triangle morphotype. 5T = 5-triangle morphotype.

Taxa	Pit Locality	Cathedral Cave (1989)	Cathedral Cave (2003)
Phenacomys gryci	x	x	x
Phenacomys sp. (not *P. gryci*)	x	x	x
Mimomys cf. *M. virginianus*	x	x	-
Ondatra sp.	x	-	x
Allophaiomys pliocaenicus	x	x	x
Mictomys cf. *M. meltoni* or *M. kansasensis*	x	x	x
Microtus meadensis	x	x	x
Microtus paroperarius	x	x	x
Microtus sp. (5T)	x	x	x
Lemmiscus curtatus (5T)	x	x	x
Lemmiscus curtatus (4T)	x	x	x

Table 3. Measurements relevant to the layout of the grid system for 2003 excavation.

Corner Stake	Depth Relative to Datum	Distance from Datum	Distance from Stalagmite
(0,0)	28 cmbd	212 cm	459 cm
(0,1) to floor	74 cmbd	273 cm	390 cm
(0,1) to corner of flowstone	60 cmbd	-	-
(0,2)	26 cmbd	352 cm	333 cm
(1,2)	32 cmbd	-	-
(2,2)	36 cmbd	302 cm	177 cm
(2,3)	34 cmbd	401 cm	104 cm
(1,3)	36 cmbd	399 cm	208 cm
(0,3)	34 cmbd	440 cm	303 cm

Table 4. Preliminary faunal list for the 2003 excavation at Cathedral Cave, Nevada. Higher taxonomic level classification follows McKenna and Bell (1997).

Higher Taxonomic Level	Lower Taxonomic Level	Comments
Gastropoda		
	Unidentified	All shells appear to be terrestrial land snails. Larger shells are likely *Oreohelix*
Osteichthyes		
	Unidentified	Numerous isolated vertebrae
Amphibia		
Anura		
	Unidentified	Sacrococcyx and vertebral elements
Reptilia		
Testudines		
	Unidentified	Two pieces of shell, appearing to represent two species were recovered
Squamata		
	Phrynosoma sp.	Several cranial elements
	Unidentified	Numerous other elements that are distinct from *Phrynosoma* have not been evaluated
Aves		
	Unidentified	Numerous cranial and post-cranial elements.
Mammalia		
Lagomorpha		
Ochotonidae		
	Ochotona sp.	See Chapter 5
Leporidae		
	Sylvilagus sp.	See Chapter 5
	Aztlanolagus agilis	See Chapter 5
	Brachylagus coloradoensis	See Chapter 5
	Brachylagus idahoensis	See Chapter 5
	Lepus sp.	See Chapter 5

Table 4 continued.

Higher Taxonomic Level	Lower Taxonomic Level	Comments
Rodentia		
Sciuridae		
	Marmota sp.	
	Unidentified	Likely includes various species of *Spermophilus* and *Tamias*
Muridae		
	Neotoma spp.	See Chapter 6
	Allophaiomys pliocaenicus	See Chapter 3
	Lemmiscus curtatus	See Chapter 3
	Microtus meadensis	See Chapter 3
	Microtus paroperarius	See Chapter 3
	Microtus sp.	See Chapter 3
	Mictomys sp.	See Chapter 3
	Phenacomys gryci	See Chapter 3
	Phenacomys sp. (not *gryci*)	See Chapter 3
	Ondatra zibethicus	See Chapter 3
	Unidentified	Likely includes species of *Peromyscus*
Geomyidae		
	Unidentified	Likely *Thomomys*, *Dipodomys*, and *Perognathus*
Erethizontidae		
	Erethizon dorsatum	
Carnivora		
Felidae		
	Unidentified	Large metapodial; *Felis concolor* or larger
Canidae		
	Vulpes vulpes	
	Vulpes sp.	
Mustelidae		
	Martes nobilis or *pennanti*	
	Mustela erminea or *frenata*	
	Mustela nigripes	

Table 4 continued.

Higher Taxonomic Level	Lower Taxonomic Level	Comments
	Taxidea taxus	
Soricomorpha		Isolated teeth and dentaries; likely *Sorex* sp.
Chiroptera		Isolated teeth; some cranial material
Artiodactyla		
Antilocapridae		
	Unidentified	Smaller than *Antilocapra*
Bovidae		
	Oreamnos sp.	
	Unidentified	Primarily post-cranial elements; based on preliminary analysis likely representing *Oreamnos* and *Ovis*
Cervidae		
	Unidentified	Post-cranial elements; likely *Odocoileus*
Perrisodactyla		
Equidae		
	Equus sp.	Mostly post-crania; a large and a small form are present

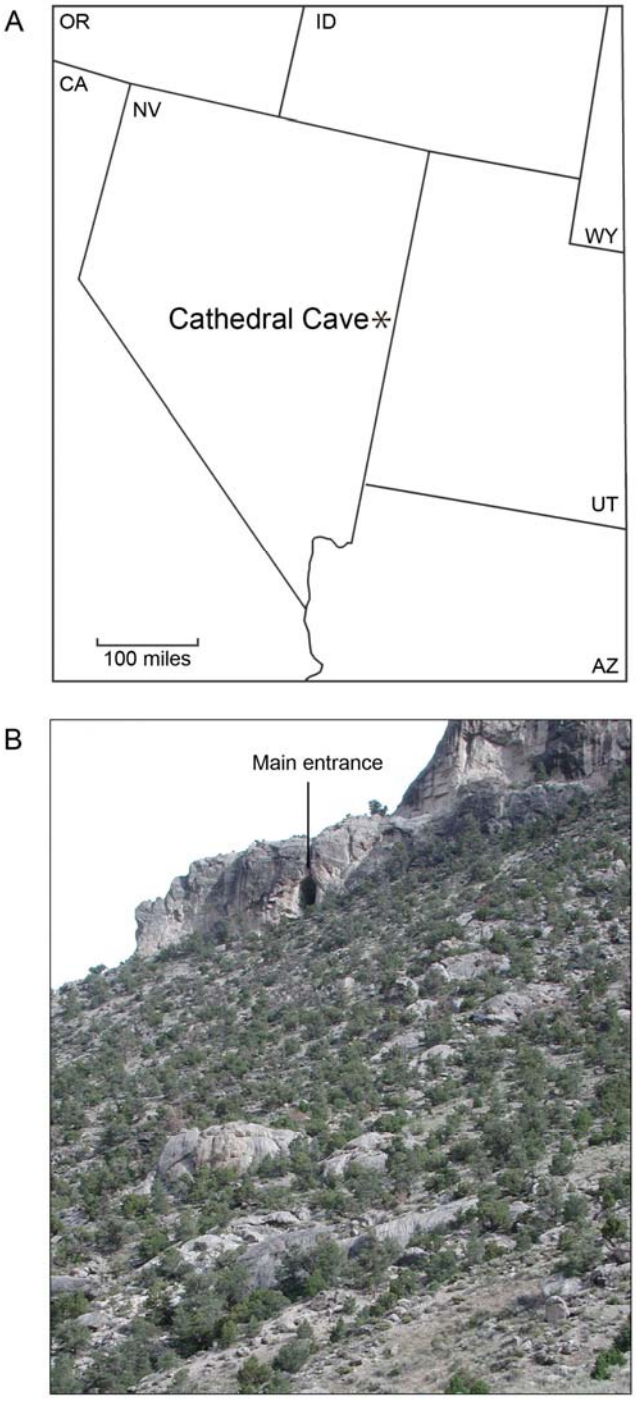


Figure 1. A. The geographic location of Cathedral Cave, Nevada. B. The main entrance to Cathedral Cave.

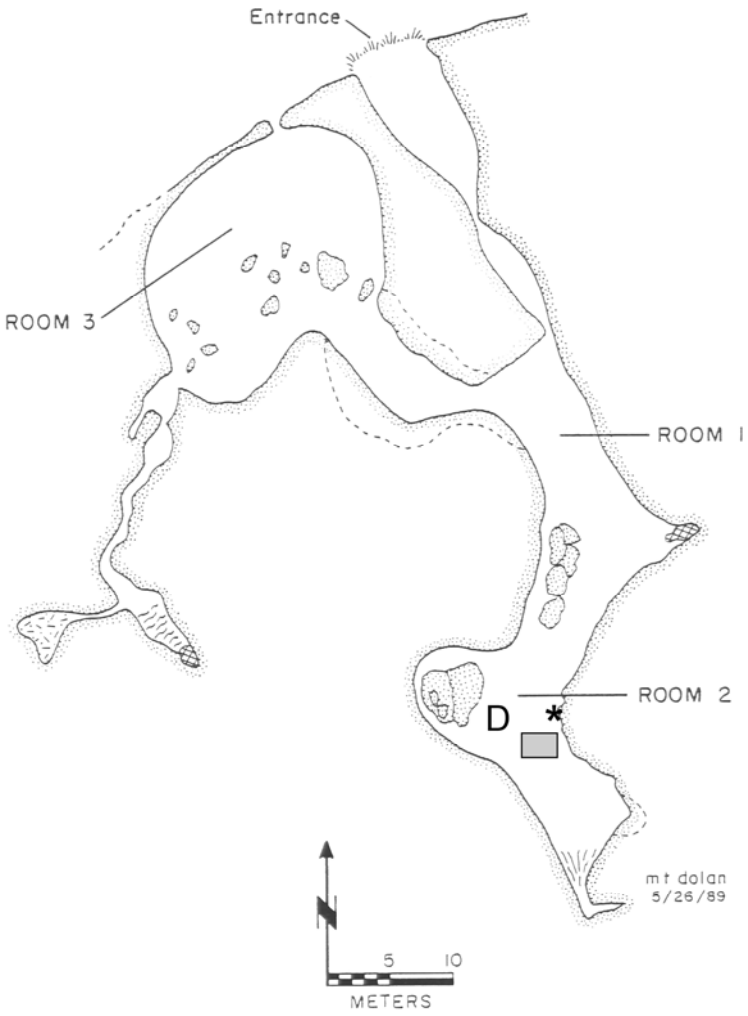


Figure 2. Plan view map of Cathedral Cave showing location of datum. 1989 and 2003 excavations = gray box. D = position of datum. * = position of stalagmite used for triangulation. Modified from Bell (1990).

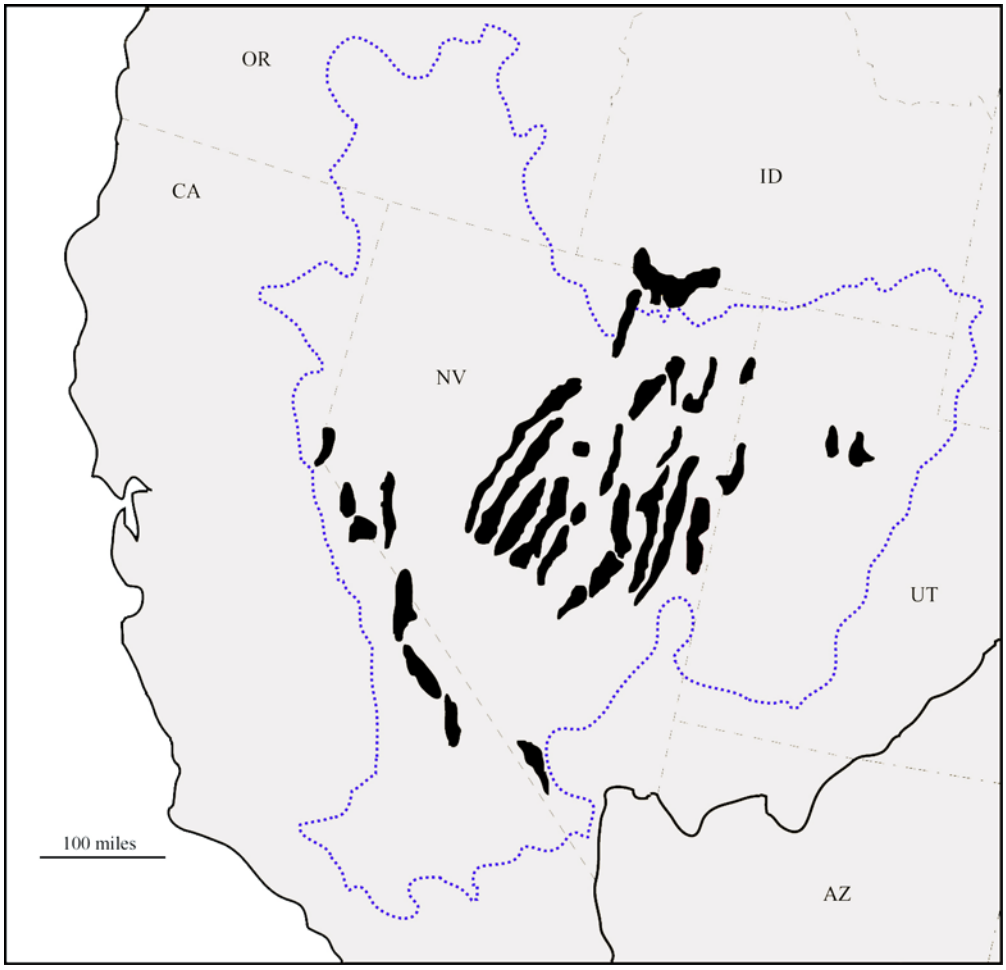
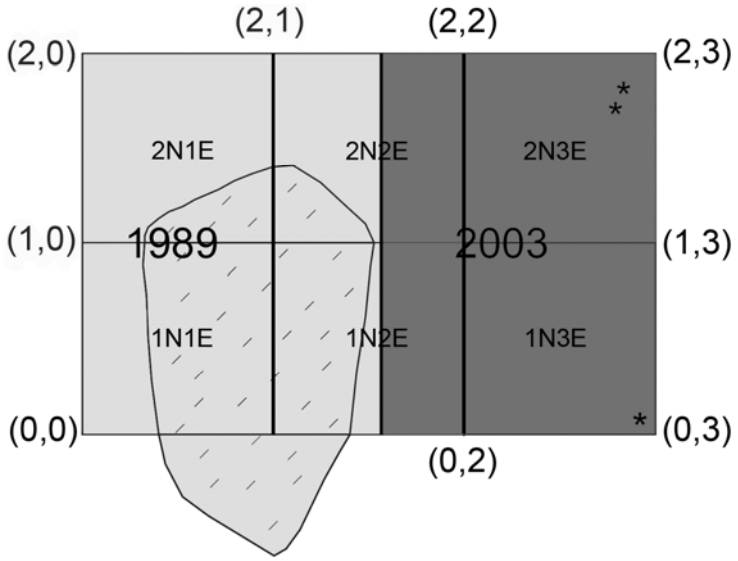


Figure 3. The hydrographic Great Basin of the western United States. Modified from Grayson (1993).

A.



B.

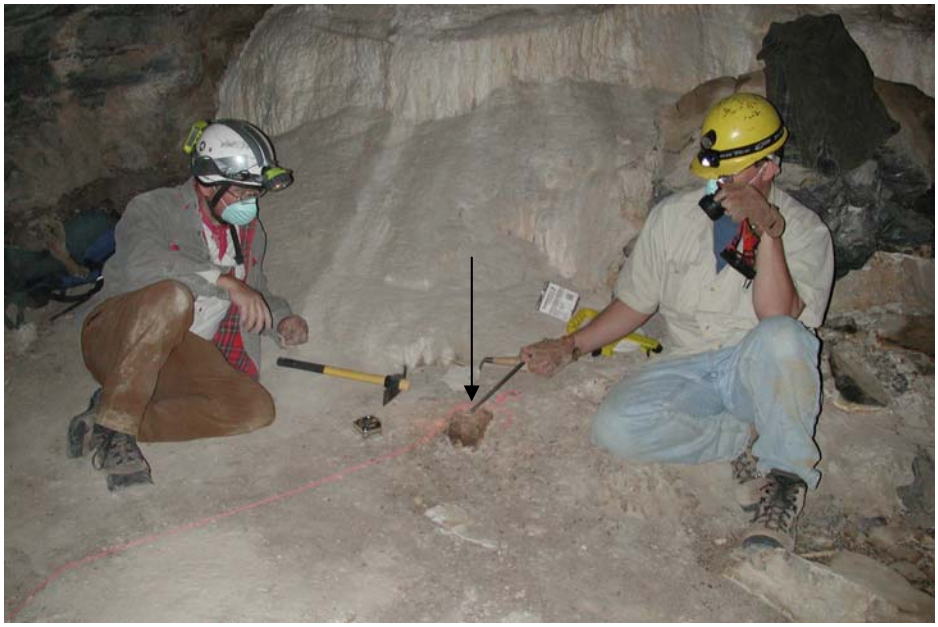
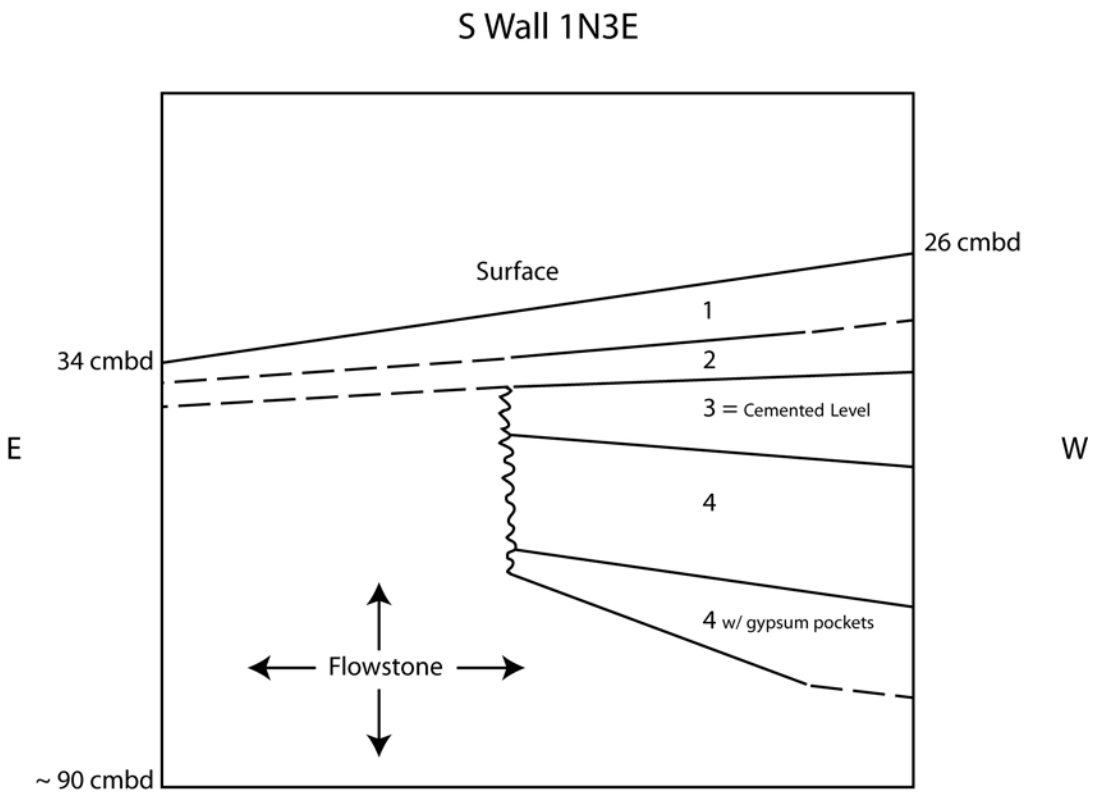
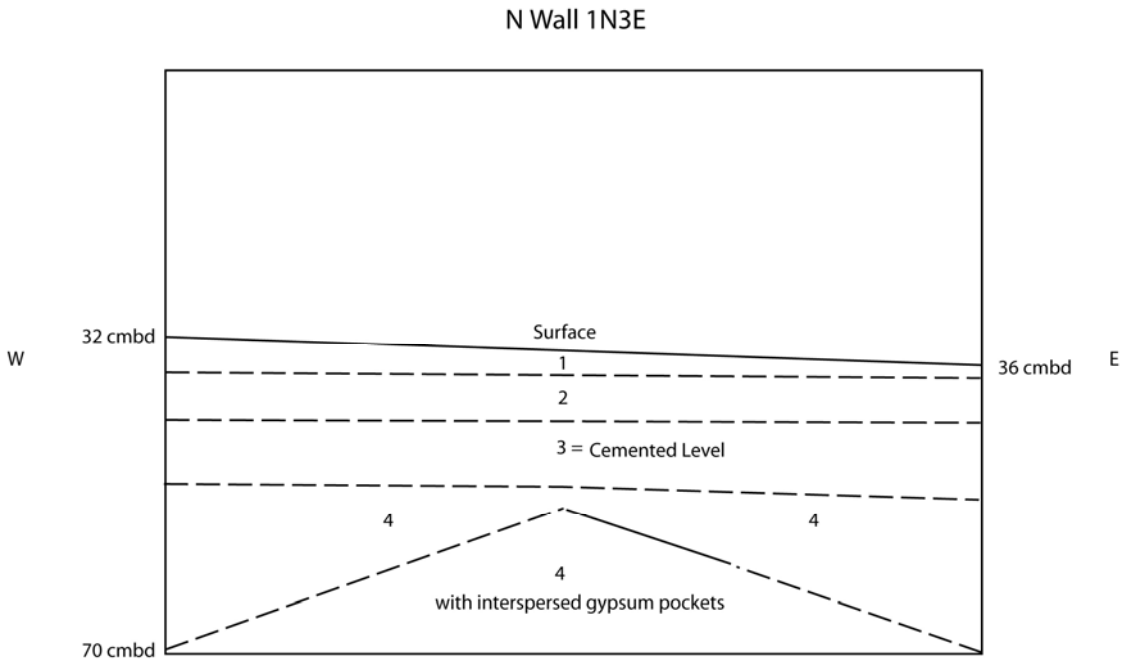


Figure 4. The grid system used in the 2003 excavation at Cathedral Cave. A. 2003 excavation grid showing area of 1989 excavation (light gray), disturbed portions of 1989 excavation (light gray with hash marks), and 2003 excavation (dark gray). North is to the top. Asterisks denote areas where flowstone samples were collected. B. Photograph of the datum (indicated by arrow) for the grid system.



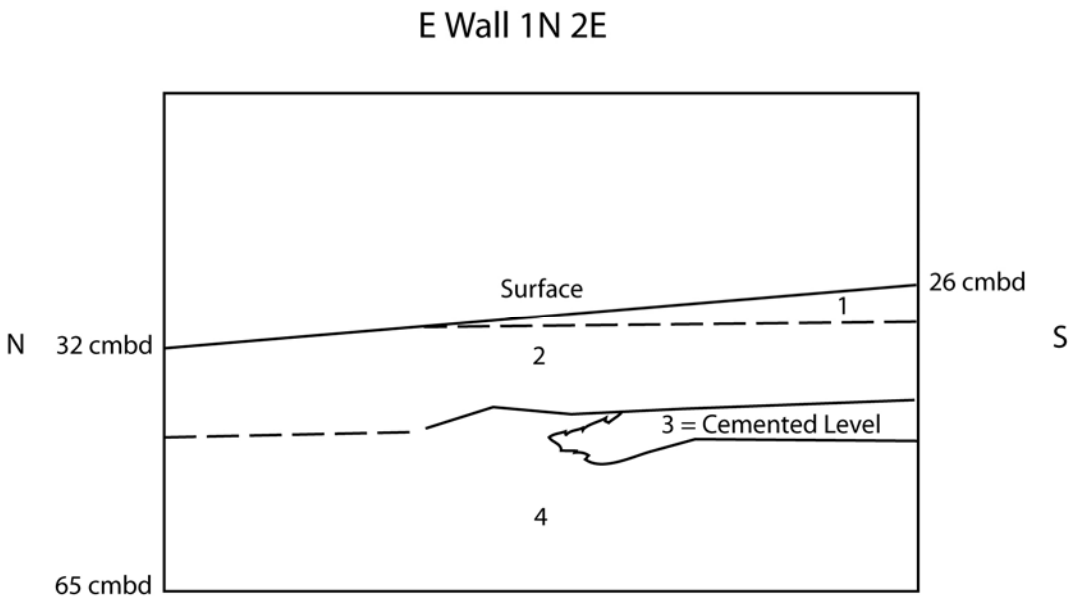
Level 1: unconsolidated sediments; 2.5Y 8/3 Pale Yellow
Level 2: unconsolidated sediments 2.5Y 6/6 Olive Yellow
Level 3: cemented sediments; 7.5 YR 5/6 Strong Brown
Level 4: unconsolidated sediments: 2.5Y 7/6 Yellow

Figure 5. Generalized cross-section of the south wall of grid square 1N 3E at Cathedral Cave.



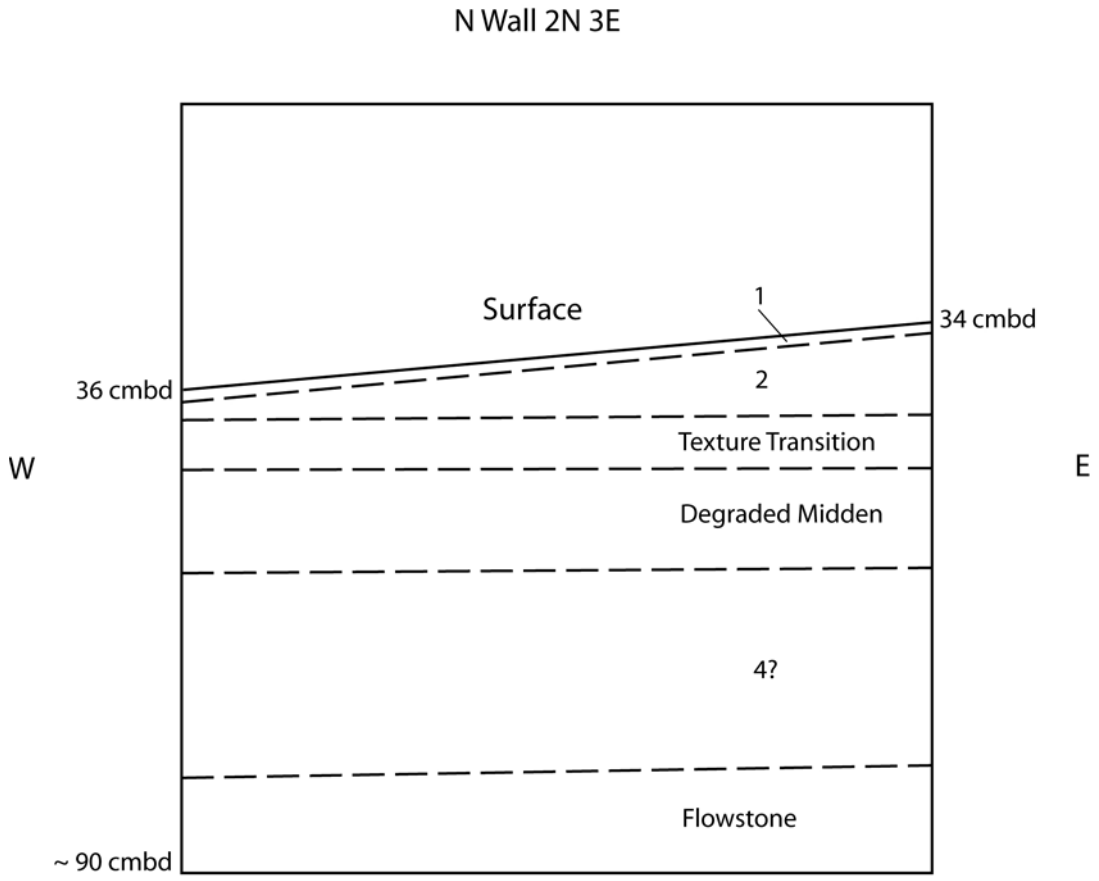
Level 1: unconsolidated sediments; 2.5Y 8/3 Pale Yellow
Level 2: unconsolidated sediments 2.5Y 6/6 Olive Yellow
Level 3: cemented sediments; 10 YR 6/6 Brownish Yellow
Level 4: unconsolidated sediments: 2.5Y 6/6 OliveYellow to 2.5Y 7/6 Yellow

Figure 6. Generalized cross-section of the north wall of grid square 1N 3E at Cathedral Cave.



Level 1: unconsolidated sediments; 2.5Y 8/3 Pale Yellow
Level 2: unconsolidated sediments 2.5Y 6/6 Olive Yellow
Level 3: cemented sediments; 7.5 YR 5/6 Strong Brown
Level 4: unconsolidated sediments: 2.5Y 7/6 Yellow

Figure 7. Generalized cross-section of the east wall of grid square 1N 2E at Cathedral Cave.



Level 1: unconsolidated sediments; = Level 1 of other profiles
Level 2: unconsolidated sediments 2.5Y 7/4 Pale Yellow
Texture Transition: some sediment compaction; 2.5 Y 7/4 Pale Yellow
Degraded Midden: unconsolidated sediments/organics; 2.5Y 7/4 Pale Yellow
Level 4?: unconsolidated sediments; 10YR 6/4 Light Yellowish Brown

Figure 8. Generalized cross-section of the north wall of grid square 2N 3E at Cathedral Cave.

Chapter 2: AN ASSESSMENT OF THE CONTRIBUTION OF FOSSIL CAVE DEPOSITS TO THE PALEONTOLOGICAL RECORD: EXAMPLES FROM THE LATE PLEISTOCENE OF NORTH AMERICA

INTRODUCTION

The completeness of the fossil record and assessment of paleobiodiversity are issues that have long concerned paleontologists. Numerous studies dedicated to assessing these issues have been conducted (e.g., Foote and Sepkoski, 1999; Alroy, 2000, 2003; Kidwell and Holland, 2002; Crampton et al., 2003; Lane et al., 2005; Cooper et al. 2006; Valentine et al., 2006; Wang and Dodson, 2006). Many of those studies deal with overall estimates of the quality of the fossil record (Badgley and Gingerich, 1998, is an exception) and focus on higher taxonomic level diversity as a measure of biodiversity and/or completeness (e.g., mammals – Alroy, 1996). Fewer studies (see Paul, 1991) focus on the examination of bias in the preservation of individual species relative to one another and might be better defined as studies of 'inadequacy' (*sensu* Paul, 1991). As with broad taxonomic-based studies, investigations focused on species-bias may also provide insight into potential gaps in the fossil record. More importantly, studies of inadequacy may provide some indication of how well different sources of fossil data reflect our perception of a historical reality (i.e., a current state of knowledge regarding the geographic and chronologic distribution of any number of taxa).

Fossils of Pleistocene age are abundant and occur in a variety of depositional environments. As a result, studies of bias in the Pleistocene fossil record can be attempted at low taxonomic levels (i.e., genus or species) and across depositional

environments. Because I conduct fieldwork in the Great Basin, where caves play a vital role in the preservation of Pleistocene vertebrates, I am interested in understanding the contribution that caves make to the fossil record as a whole. Specifically, do caves contribute unique knowledge about individual species or species groups? Additionally, what features of a species or species group (e.g., evolutionary history, body size, convergent life history patterns) might impact the likelihood that an organism is preserved in the cave record? If caves contribute uniquely to the fossil record and that contribution is correlated to life history traits of species or species groups, we might be better able to make predictions about certain types of taxa that are most likely to be absent or underrepresented in portions of the fossil record that lack cave deposits.

In order to address these questions I formulated a series of simple hypotheses that could be evaluated using the large paleontological data set available for the late Pleistocene of North America. I limited my analyses to three areas, including the overall contribution of caves to the fossil record, the role of caves in sampling taxa from habitats where fossil records are likely to be rare, and the role of life history features of individual species in determining where a species is likely to be preserved.

I first examined individual species representation in cave deposits versus representation in other depositional settings, the null hypothesis being that no differences would be evident. Second, I examined the role of caves in sampling taxa from habitat types (i.e., montane habitats) where fossil records might otherwise be limited or lacking. Because the Great Basin now retains populations of mammals that are restricted to high elevation, montane habitats, where fossils are less likely to be preserved due to a lack of depositional environments, I wanted to examine possible differences in preservation

patterns during periods of restricted distribution (Holocene) versus periods where taxa were thought to be more widespread (late Pleistocene). Using the late Pleistocene and Holocene as proxies for the geographic distribution of taxa, the null hypothesis for this part of the project was that there would be equal representation of montane taxa in cave deposits versus other depositional settings irrespective of the geographic distribution of individual taxa. Finally, I examined the relationship of both body size and modern geographic distribution of individual taxa with the representation of those taxa in cave deposits versus other depositional settings. For body size, my null hypothesis was that size has no effect on the likelihood that an individual species will be preserved in a particular depositional setting. For geographic distribution, my null hypothesis stated that the exclusion of cave deposits would have no significant effect on our understanding of an organism's past geographic distribution.

CAVES AS A PALEONTOLOGICAL DATA SOURCE

Caves are regarded as excellent resources for gathering paleontological data and have long been known to preserve the remains of fossil vertebrates (e.g., Harris, 2005; Lundelius, 2006). Early reports on bone-bearing, North American cave deposits were primarily descriptive (e.g., Cope, 1895, 1896, 1899; Brown, 1908; Stock, 1936), but provided an indication of the potential of caves as a paleontological data source in North America. Recent compilations (e.g., Schubert et al., 2003) continue to illustrate this point, and many studies are now moving beyond the descriptive to focus on broad taphonomic and evolutionary questions (e.g., Hadly, 1999). While there are challenges to

working in cave deposits (e.g., complex depositional environments [Sutcliffe, 1970; Gilleson, 1996; Harris, 2005]), there are certain documented advantages to working on vertebrate assemblages from these deposits.

Several factors contribute to the utility of caves as paleontological data sources. One of the most appealing (and sometimes overwhelming) aspects of conducting paleontological research in cave deposits is the highly fossiliferous nature of many of them (Fig. 9). In many cases, cave deposits preserve large sample sizes of taxa that allow for the evaluation of evolutionary patterns (e.g., Barnosky and Bell, 2003).

Second, cave deposits often preserve rare modes of fossilization. Multiple sites in arid regions of the southwestern United States preserve soft tissues and/or dung deposits. Notable among these are Rampart Cave, AZ (Laudermilk and Munz, 1938; Martin et al., 1961; Mead and Agenbroad, 1992), Gypsum Cave, NV (Stock, 1931; Harrington, 1933; Laudermilk and Munz, 1934), and Bechan Cave, UT (Mead et al., 1986). These, and other localities (see review by Lundelius, 2006), offer important insights into dietary and behavioral patterns of extinct taxa, and preserve ancient DNA (Hadly et al., 1998, 2003; Poinar et al., 1998).

Additionally, caves often preserve paleoecological data that are independent of fossil bone. Woodrat (*Neotoma*) middens, common in caves in the western United States, may provide direct paleobotanical data (Betancourt et al., 1990). Isotopic analysis of speleothems also has become a powerful method of interpreting past climatic conditions over relatively detailed chronologies (e.g., Musgrove et al., 2001).

Finally, caves are fairly widespread across the continental United States (Fig. 10). Even in some areas that lack major karst topography, cave deposits have a documented

role in our understanding of regional faunal histories. Areas such as the Great Basin and Grand Canyon have late Pleistocene vertebrate records built almost entirely upon excavated cave deposits (Grayson, 1993; Mead et al., 2003). This suggests that wherever caves are present, they may act as valuable repositories of paleontological data, particularly when the complexities of conducting paleontological research in cave deposits can be overcome or minimized through careful excavation.

PREVIOUS WORK

Previous work related to the importance of cave deposits focused on a variety of topics including the overall contribution of caves to the Quaternary fossil record and the role of caves in the preservation of environmentally sensitive taxa (Toomey, 1997), the potential of caves to preserve carnivoran remains (Muñoz-Durán and Van Valkenburgh, 2006), the reliability of cave deposits for recording local ecosystems and faunal assemblages (Hadly, 1999), the importance of caves as repositories of paleoecological data (Davis, 1990), a review of taphonomic factors that influence fossil depostion in caves (Harris, 2005), and a general review of the importance of cave deposits for vertebrate paleontology across the geologic record (Lundelius, 2006). Because cave deposits may retain fairly complete records of local biotas, including rare taxa, the consideration of multiple cave deposits from a given area may provide relatively accurate reconstructions of regional biotas given some knowledge of taphonomic biases (Hadly, 1999).

This last point is an especially important one, because a significant body of work addresses the effects of different taphonomic processes on both cave and non-cave

deposits (e.g., Behrensmeyer and Hill, 1980; Brain, 1981; Andrews and Evans, 1983; Emslie, 1988; Hoffman, 1988; Andrews, 1990; Schmitt and Juell, 1994; Cruz-Uribe and Klein, 1998). The taphonomic processes that contributed to the formation of the deposits included in the following analysis are not necessarily equal. However, my primary objective is to evaluate the importance of cave deposits versus non-cave deposits as a whole. Therefore, differences in the taphonomic setting of individual deposits are not considered.

TAXONOMIC SAMPLES AND METHODS

In order to evaluate the role of cave deposits in the preservation of individual mammal species, I utilized summary paleontological data provided by the FAUNMAP Working Group (1994). Although additional localities have been reported since 1994, I limited my analysis to the published FAUNMAP data because they represents a large sample of localities and taxa, and should serve as a proxy for patterns of taxonomic preservation even with the addition of new data. Additionally, a new, updated version of FAUNMAP is forthcoming (E. Lundelius, personal communication), and the reproduction of those data in this context would be redundant. Localities regarded as 'caves' may include caverns, natural traps, and rock shelters (Davis, 1990). Data listed below as ‘late Pleistocene’ includes data listed as ‘Late Wisconsin’, ‘Glacial’, ‘Full Glacial’ and ‘Late Glacial’ in FAUNMAP and encompasses a range from 40,000 yr B. P. to 9500 yr B. P.

Cave Representation Values—For 146 individual species reported from the late Pleistocene record summarized by FAUNMAP, I calculated a fraction (*C/T*) based on the

number of cave records (*C*) versus total number of all records (*T*). For example, pika (*Ochotona princeps*) was reported from 18 cave deposits (*C*=18) out of 24 total (*T*). The cave representation value (*C/T*) is 0.75 for pikas. In order to provide some measure of the relative importance of cave records for individual species, I calculated the mean *C/T* value (C/T_{all}) and standard deviation (*SD*) for all taxa as a group for comparison with the *C/T* value of individual taxa. Taxa with *C/T* values exceeding C/T_{all} + one standard deviation were categorized as having high representation in the cave record; taxa with values within C/T_{all} ± one standard deviation were categorized as having moderate representation; and taxa with values lower than C/T_{all} - one standard deviation were categorized as having low representation.

I performed similar operations for ten traditionally recognized ordinal groups (e.g., $C/T_{Rodentia}$) in order to evaluate differences in species within groups of closely related-taxa. This exercise was intended to distinguish differential representation among species that share a similar evolutionary pathway, and to allow for discussion of why in-group differences may exist. Additionally, this provides baseline data for future, more detailed, studies that examine additional natural history traits in determining representation in cave deposits among related taxa.

Spilogale gracilis and *Sylvilagus aquaticus* have no reported late Pleistocene records and were excluded. All data for *C* and *T* were tabulated manually. Summary statistics were derived using data analysis tools in Microsoft Excel©.

Because I used FAUNMAP as a source of primary data, certain biases and limitations were incorporated into this project. First, I assumed that the identifications of taxa included in the FAUNMAP database were correct. The summary data utilized here

are dependent upon initial specimen identifications made by many researchers who likely adhered to different identification criteria. While this seems self-evident, there are some instances where it can be argued that the taxonomic resolution presented in FAUNMAP do not accurately reflect the level at which certain taxa can be reliably identified. For example, the ability to provide a reliable identification of isolated teeth of species of *Microtus* has been questioned (Bell et al., 2004a), but eight species of *Microtus* are differentiated in the FAUNMAP database. Other analyses (i.e., phylogenetic studies) may show that the species resolution summarized in the FAUNMAP database is influenced by geographic or temporal assumptions. By this, I mean that geographic or temporal characteristics associated with individual faunas likely had a part in the primary identification process prior to incorporation into FAUNMAP. Additionally, in order to be included in FAUNMAP, a locality had to have ten or more taxa associated with it and some form of precise age control (e.g., radiocarbon dates; FAUNMAP Working Group, 1994). Therefore, no localities without external age control or containing less than ten mammalian taxa are included in my analysis.

Cave Representation and Montane Taxa—In order to explore the possibility that caves contribute rare records of taxa that are known to inhabit areas of high elevation, I calculated cave representation values for 11 'montane' taxa known to occur in the Great Basin. Because the biogeographic distribution of these taxa in the Great Basin has fluctuated through time (Grayson, 1993), I calculated two separate representation values (one for the late Pleistocene, one for the Holocene) for each taxon. Given that the taxa considered in this context are purported to have been more widely distributed during the late Pleistocene than the Holocene, higher Holocene cave representation values for

'montane' taxa than Pleistocene values for those same taxa would support a prediction that caves provide a sampling of distinct habitats (e.g., montane habitats).

Cave Representation, Body Size, and Geographic Distribution—The importance of caves for preservation of small-bodied mammalian fossils was emphasized by Toomey (1997). However, no analysis was available to support a correlation between body size and the likelihood that organisms will be preserved preferentially in caves versus other types of deposits. To evaluate that relationship, I compiled minimum (n = 113) and maximum (n = 115) body mass data for many of the mammalian taxa that I used to compile cave representation values (see Appendix 2). Using these data I created scatter plots and plotted R-squared values for the graphs in Microsoft Excel© for both minimum and maximum body size versus cave representation values for all mammal taxa and five taxonomic groups (insectivoran, carnivoran, artiodactyls, rodents, and lagomorphs). In some instances, especially for extinct taxa, body mass data were not found and those taxa were not included in this particular analysis. A recent study by Muñoz-Durán and Van Valkenburgh (2006) addressed similar issues of body size, habitat preferences, and preservation of carnivorans in different depositional settings. Comparison of their study with my study is presented in the discussion (see below).

Because the recognition of individualistic biogeographic shifts in mammal species has been a major contribution to our understanding of faunal response to climate change (FAUNMAP Working Group, 1996), I also evaluated the importance of cave data to our understanding of the biogeographic history of individual species during the late Pleistocene. In order to examine the effect of cave deposits on biogeographic data, I used locality records for species of sciurids presented in FAUNMAP (see Appendix 3) and

created new sets of distribution maps that combined all late Pleistocene records for individual species of sciurid rodents. In certain instances where the numbers of records were high, I imported longitude and latitude data into a web-based map generator available through the USGS Woods Hole Science Center (http://woodshole.er.usgs.gov/mapit/) in order to confirm that all records were included in the new distribution maps. I limited my assessment to sciurid rodents because they inhabit a fairly broad range of habitats today, are fairly widespread as a group, and have been used to make paleoenvironmental inferences (e.g., Harris, 1985; Lundelius, 1985a; Goodwin, 2004). The first set of maps was based solely on cave deposits and the second set excluded cave deposits. Major differences in distribution patterns among these maps provide some indication of the contribution of cave deposits to our understanding of past biogeographic patterns.

RESULTS

Cave Representation Values of All Taxa—As of 1994, the total number of late Pleistocene taxonomic records from cave deposits was 1634 and represented nearly 52% of the total number of all reported records (3150; based on FAUNMAP Working Group, 1994). Table 5 summarizes the calculated *C/T* values for all individual taxa. The C/T_{all} value was 0.624 with a $SD = 0.244$. Because the range of $C/T_{all} \pm$ one standard deviation includes the value 0.50, where cave representation would be equal to representation in other types of deposits, the null hypothesis cannot be rejected outright for all species. Rather, it suggests that rejection (or acceptance) of the null hypothesis is dependent upon the individual species under consideration. Fourteen of 146 species had *C/T* values of

1.0, meaning that they are only known from cave deposits in the late Pleistocene. The majority of taxa (103) had a *C/T* value that exceeded 0.5. Conversely, only two species (*Mammuthus primigenius* and *Spermophilus franklini*) had *C/T* values of 0. Threshold values for categorization were 0.380 for low representation and 0.868 for high.

Twenty-four of 146 species were categorized as having low representation in the fossil record of caves. Figure 11 summarizes traditional mammalian orders with species having low, moderate, and/or high values. Ordinal groups that contain species that scored in the low category were rodents, artiodactyls, proboscideans, carnivorans, and xenarthrans. Taxonomic groups with no representatives in the low category were marsupials, insectivorans, chiropterans, perissodactyls, and lagomorphs. With the exception of chiropterans and proboscideans, all clades had at least one representative in the moderate category.

Twenty-five of 146 species were categorized as having high representation in the fossil record of caves. Ordinal groups with species in the high category were insectivorans, chiropterans, artiodactyls, carnivorans, rodents, and lagomorphs. Taxonomic groups with no species in the high category were marsupials, xenarthrans, perissodactyls, and proboscideans.

Among higher taxonomic level groupings there is some differentiation in how taxa are distributed across categories (Fig. 11). Proboscidea (low), Perissodactyla (moderate), Marsupialia (moderate), and Chiroptera (high) each occurred within only a single category. There is a possibility that the distribution of these groups across categories is an artifact of inadequate sampling (number of species = < 5). However, it seems plausible that natural history characteristics common in certain mammalian orders

may contribute to the pattern of distribution for proboscideans (large body size) and chiropterans (troglodyte) in cave deposits versus open-air deposits (Fig. 12).

Cave Representation Values by Taxonomic Group—Table 6 summarizes data for group-level analyses (e.g., $C/T_{Rodentia}$) and provides threshold values for categorization. In-group discussions of taxa within a particular grouping are presented individually below and focus on those taxa that fall outside the moderate category. *Didelphis virginiana* was the only marsupial species and is not considered here.

Xenarthrans: Of the five xenarthrans considered, *Dasypus bellus, Holmesina septentrionalis* and *Megalonyx jeffersoni* had moderate representation. *Nothrotheriops shastensis* had high representation relative to other xenarthrans and likely indicates utilization of caves as shelters by that species. Several cave localities in the southwestern United States preserve dung deposits attributed to *N. shastensis* (McDonald, 2003). No current evidence suggests that caves were commonly used as shelters by other species of extinct sloth in North America. *Paramylodon* (formerly *Glossotherium*) *harlani* shows low representation, and although it is speculative, the large body size of this taxon may have contributed to a dearth of remains in cave deposits. Newer summary data of the distribution of *P. harlani* within cave deposits (McDonald, 2003) indicated a slightly higher percentage of cave records than found on the basis of the FAUNMAP data that was utilized in my study.

Insectivorans: *Sorex cinereus* had the lowest representation relative to other insectivorans. *Sorex dispar*, *Sorex fumeus*, and *Parascalops breweri* had high representation relative to other insectivorans. All three taxa with high representation in the cave record have modern geographic distributions that are restricted to areas of the

northeastern United States that overlap major karst features (Wilson and Ruff, 1999; Fig. 10). *Sorex cinereus* is more widely distributed across the northern portions of the United States (Wilson and Ruff, 1999), perhaps minimizing the importance of caves in the preservation of this taxon.

Chiropterans: *Eptesicus fuscus* had a slightly lower cave representation value (0.947) relative to *Myotis velifer* and *Pipistrellus subflavus* (both 1.0). This was the result of a single record from a non-cave deposit (Morgan, 1985). The wider geographic distribution of *E. fuscus* would possibly make it more likely to occur in different types of deposits, but such a statement is unsupported at present.

Carnivorans: Four taxa (*Smilodon* sp., *Panthera leo atrox*, *Lontra canadensis*, and *Arctodus simus* had low representation relative to other carnivorans, and four taxa (*Mustela erminea*, *Mustela nigripes*, *Mustela nivalis*, and *Bassariscus astutus*) had high representation relative to other carnivorans. A previous study by Muñoz-Durán and Van Valkenburgh (2006) illustrated the importance of cave deposits for the preservation of small-bodied carnivorans, and the results presented here appear consistent with those interpretations.

Proboscideans: *Mammut americanum* had high representation relative to other proboscideans. *Mammuthus primigenius* had low representation relative to other proboscideans. Because of their body-size, a lack of proboscidean fossils in cave deposits is not surprising. Although the use of caves by elephants is not unknown (Redmond, 1984), it is more likely that most of the records of proboscideans from North American cave deposits reflect the predatory behaviors of other mammals (e.g., Friesenhahn Cave; Graham, 1976).

Perissodactyls: *Equus conversidens* had high representation relative to other perissodactyls. As with species of proboscideans, the cave representation values of individual perissodactyls seem more likely to represent the dietary and taphonomic biases of their predators.

Artiodactyls: Artiodactyl species with low representation values relative to other artiodactyls included *Camelops hesternus*, *Cervalces scotti*, *Bison bison*, and *Bootherium bombifrons*. Artiodactyl species with high representation values relative to other artiodactyls included *Alces alces*, *Navahoceros fricki*, and *Ovis canadensis*. Surprisingly, *Oreamnos harringtoni*, an extinct mountain goat commonly associated with caves (Mead et al., 1986), has a *C/T* value that is moderate compared to other artiodactyls. For taxa not typically associated with caves, it is likely that predators or scavengers had a large impact on the *C/T* value through the introduction of artiodactyls carcasses into cave deposits. More so than in other groups considered in this study, variations in the sample sizes of individual artiodactyl species likely had an impact on categorization. The range of the number of records per species for artiodactyls was greater than all except Proboscideans. Some artiodactyls are very well known from the late Pleistocene record (e.g., *Bootherium bombifrons* total number of records = 102) whereas others are not (e.g., *Alces alces* total number of records = 3).

Rodents: Rodent species with low cave representation values relative to other rodents included *Cynomys leucurus*, *Cynomys ludovicianus*, *Spermophilus franklini*, *Spermophilus richardsonii*, *Castoroides ohioensis*, *Geomys bursarius*, *Thomomys talpoides*, *Neofiber alleni*, *Ondatra zibethicus*, *Onychomys leucogaster*, and *Reithrodontomys megalotis*. Rodents with high cave representation values relative to

other rodents included *Marmota flaviventris, Spermophilus variegatus, Glaucomys sabrinus, Glaucomys volans, Pappogeomys castanops, Napeozapus insignis, Dicrostonyx torquatus, Microtus chrottorrhinus, Microtus mexicanus, Baiomys taylori, Neotoma mexicana*, and *Erethizon dorsatum*. Possible explanations for the distribution of cave representation values among rodents are difficult to assess at present. As with other taxa, predatory behavior might be a factor in determining which rodents were incorporated into cave deposits. However, rodents as a group are quite diverse and have a wide variety of behaviors and habitat tolerances that could influence their cave representation values. For instance, both woodrats (*Neotoma*; Betancourt et al., 1990) and porcupines (*Erethizon dorsatum*; Wilson and Ruff, 1999) are known to utilize caves as denning sites and both have fairly high cave representation values. Because rodents are such a diverse group, future evaluation at higher taxonomic levels might clarify possible biases in the distribution of cave representation values.

Lagomorphs: *Lepus townsendii* had a low cave representation value relative to other lagomorphs, whereas *Lepus americanus* and *Sylvilagus nuttallii* had high representation values. Lagomorphs, as a group, are not known to utilize caves as shelters, which suggests that prey selection would account for the distribution in cave representation values.

Cave Representation Values and Montane Taxa—Table 7 summarizes the late Pleistocene and Holocene cave representation values for 11 taxa that commonly occur in mountainous regions of the Great Basin. In no cases were the values equal, requiring that the null hypothesis of no differences between late Pleistocene and Holocene *C/T* values be rejected.

Rejection of the null may not be surprising, but the relationship of late Pleistocene to Holocene values was unexpected given my prediction based on the biogeographic history of the Great Basin. In only two cases (*Sorex palustris* and *Zapus princeps*) *C/T* values for the Holocene exceeded those of the late Pleistocene. For the other nine taxa considered, Holocene *C/T* values exceeded late Pleistocene values. This suggests that caves were not necessarily better samplers of taxa that had habitat affinities (i.e., montane habitats) that resulted in more restricted distributions from the late Pleistocene to Holocene. In other words, taxa that inhabit unique habitats may not be less likely to appear in the fossil record than those that have broader habitat tolerances. However, the Holocene has some unique characteristics that might be influencing the results of this particular analysis.

Prior to the Holocene, the primary pathways for mammals to be introduced into cave deposits (besides inhabiting caves) included predation by birds of prey and/or mammalian carnivores, and through the collecting activities of woodrats (*Neotoma*). During the Holocene a new taphonomic vector (*Homo sapiens*) became widespread in North America and may have contributed to an increase in the appearance of certain taxa in fossil deposits. Another possibility is that the numbers reflect a heavy research focus on archaeological sites from the Holocene, thereby influencing the *C/T* values. Nevertheless, the data presented here suggest that taxa that inhabit montane habitats are still likely to be preserved in the fossil record even though they inhabit areas that are not ideal for fossil preservation.

Cave Representation Values and Body Size—Scatter plots of cave representation versus minimum and maximum body mass (Figure 13) showed little correlation and this

was reflected in the R-squared values for each scatter plot. R-squared values for *C/T* versus body mass were 0.0064 (minimum body mass) and 0.004 (maximum body mass) suggesting no significant correlation between *C/T* and body mass.

In order to examine the possible effects of the wide range of body sizes included in my analysis (0.002 kg to 907.0 kg) I also calculated separate R-squared values for *C/T* versus body mass for 5 ordinal groups (insectivorans, carnivorans, artiodactyls, rodents, and lagomorphs). Summaries of R-squared values for cave representation versus minimum and maximum body mass in ordinal groups are presented in Tables 8 and 9. Cave representation values had the strongest correlations with maximum ($R^2 = 0.151$) and minimum ($R^2 = 0.081$) body mass of lagomorphs. These low correlation values suggest that although caves may preserve a large percentage of small-bodied organisms (i.e., Toomey, 1997), body size is not necessarily a determinant of which species are recorded in the fossil record of caves. The taphonomic processes that produce cave deposits and the configurations of the caves themselves (e.g., pit trap vs. walk-in entrance) appear random enough that mammals of any body size may be recorded. That is not to say that mammals of all body sizes will be preserved at equal rates. In fact, when the abundances of species preserved within cave deposits are evaluated, there are evident differences in the preservation rates of large and small carnivores (Muñoz-Durán and Van Valkenburgh, 2006).

Cave Representation Values and Biogeography—Figures 14-32 illustrate variation in the recovered paleobiogeographic distribution of sciurid species when cave data are included or excluded. Distribution maps of individual species that have notable differences are discussed below.

Cynomys ludovicianus (Figure 16): With the exclusion of cave deposits the southernmost records of *Cynomys ludovicianus* disappear, implying a more restricted distribution than is evident when all records are considered. Conversely, if only cave records were available, the late Pleistocene distribution would appear to be restricted to New Mexico and Texas. Such a scenario could lead to serious error in reconstructing biogeographic range shifts through time.

Marmota flaviventris (Figure 17): Cave deposits account for nearly all records of *Marmota flaviventris* and as such nearly mirrors the map containing all records. The notable exceptions are the northernmost record in Montana and an extralimital record from Nebraska. Cave records account for all of the southernmost distribution of this taxon.

Marmota monax (Figure 18): As with *Cynomys ludovicianus*, the late Pleistocene distribution of *Marmota monax* would appear much more restricted if cave deposits were not available. When considering the late Pleistocene distribution as a whole (i.e., an imaginary line drawn around all of the outermost data points), the map restricted to cave deposits (Fig. 18, middle) mirrors the distribution based on all records.

Spermophilus franklini (Figure 19): *Spermophilus franklini* is one of the few taxa for which cave fossils are unknown. Therefore, caves add nothing to the record of this taxon.

Spermophilus tridecemlineatus (Figure 24): The late Pleistocene distribution of *Spermophilus tridecemlineatus* is quite different when caves and non-caves are considered separately. When caves only are considered, (Fig. 24, middle) the distribution as a whole roughly matches that when all types of localities are considered (Fig. 24, top).

In contrast, when caves are excluded (Fig. 24, bottom) the distribution appears restricted almost exclusively to the Great Plains.

Spermophilus variegatus (Figure 25): Cave deposits closely approximate the late Pleistocene distribution based on all localities. The only non-cave record is an extralimital record from Colorado that represents a broader eastern distribution for the species during the late Pleistocene.

Sciurus carolinensis (Figure 26): When considered as whole distributions, the caves-only map and non-caves map nearly divide the overall late Pleistocene distribution in half. Caves account for the northeastern portion of the distribution whereas non-caves account for the southwestern portion of the distribution.

Multiple Species: Cave records, considered as a whole, encompass major or entire portions of the late Pleistocene distribution of *Tamias minimus* (Fig. 28), *Tamias striatus* (Fig. 29), *Tamiasciurus hudsonicus* (Fig. 30), *Glaucomys sabrinus* (Figure 31) and *Glaucomys volans* (Fig. 32). The exclusion of cave deposits results in a much more restricted or unrecognized distribution of these taxa relative to the paleodistribution based on data from FAUNMAP.

DISCUSSION AND CONCLUSIONS

My results show that caves make an important contribution to the Pleistocene faunal record of the United States, but this is not a novel observation. Previous authors explicitly acknowledged the contribution of cave deposits to the fossil record (e.g., Toomey, 1997; Lundelius, 2006). My purpose in conducting this research project was to examine specifically how cave deposits influence our understanding of the fossil record.

If cave deposits contribute novel information (e.g. taxonomic, geographic, etc.), then we may be able to speculate on types of data that are missing for time periods that have no cave record or lacked the taphonomic vectors known to facilitate the incorporation of vertebrate remains into cave deposits.

The fact that the overall cave representation value for all taxa (C/T_{all}) was 0.624 suggests that caves have an important role in the number of locality records for any given taxon. For 14 taxa, caves were the only source of data in the late Pleistocene, whereas only two taxa were not found in any cave deposits. For 103 taxa, *C/T* values were above 0.5 indicating that a majority of their locality records are based on preservation in cave deposits. Therefore, time periods and geographic regions characterized by the presence of cave deposits likely retain more accurate representations of species richness.

The variation in cave representation values between species of particular mammalian orders (e.g., rodents versus perissodactyls) is difficult to assess. For example, I am hesitant to predict that an expanded analysis would show that perissodactyls have moderate cave representation values relative to other taxa. The groups that had the fewest taxa had the least diverse categorical representation (Figure 11), indicating that the range of category diversity found for mammalian orders may be related to differences in sample size and not to shared evolutionary traits, at least at the taxonomic level considered here.

Similarly, it is difficult to evaluate comparisons of cave representation values for species within a particular taxonomic group (e.g., within xenarthrans). Certainly for those taxa known to utilize cave deposits for roosts or dens (e.g., chiropterans, *Bassariscus astutus*) there are behavioral explanations for high cave representation

values. For some taxa (e.g., *Lepus americanus, Sylvilagus nuttallii*) the reasons are less clear, particularly because the criteria used to identify individual species may differ among researchers and between taxonomic groups.

The results of the comparison of Pleistocene and Holocene cave representation values of eleven 'montane' taxa were surprising. Although the relative abundance of these taxa (see Table 7) in any particular deposit was not calculated, the fact that they were more common in non-cave deposits was unexpected. Calculated values for montane taxa suggest that some taxa that inhabit areas that are not ideal for fossil preservation (e.g., mountain ranges with no caves) may still appear in the fossil record. In such instances, erosional and/or taphonomic processes are of utmost importance. As mentioned above, the arrival of humans as a taphonomic agent may have influenced the pattern observed here. Comparison of Pleistocene and Holocene localities that lack evidence of archaeology, or pre-*Homo sapiens* localities that correlate with known climatic shifts, might clarify whether humans had an effect on the cave representation values found in this study for 'montane' taxa.

The results of my examination of the effects of cave deposits on our understanding of geographic distribution indicates the importance of caves in providing a more detailed picture of the paleobiogeography of mammalian taxa. With few exceptions (e.g., *Cynomys ludovicianus*; Fig. 16), caves provide the marginal distribution records of sciurid taxa. In many instances, distributions based solely on cave records mirror the known distribution based on all records. Although other taxa should be evaluated, this result suggests that time periods lacking cave deposits may produce more biased data with regards to the paleodistribution of mammalian species.

The fidelity of at least some cave deposits to local ecosystems has been shown to be high (Hadly, 1999). A similar type of study for open-air deposits has been undertaken for modern depositional environments in Africa (Behrensmeyer and Dechant Boaz, 1980), but that study focused primarily on larger mammals and may not be directly comparable to North American ecosystems. Perhaps one of the most compelling studies that might be undertaken would be comparison of Holocene cave deposits (e.g., Hadly, 1999) with open-air deposits of known taphonomic origin, similar age, and similar geographic location. Such a comparison could further clarify how accurately different depositional settings record faunal assemblages through time.

In summary, caves do preserve unique species records, and they preserve a large percentage of the individual species records for late Pleistocene North American mammals. As such, caves make a significant contribution to the adequacy of the fossil record. Time periods or geographic regions that lack cave deposits likely contribute to more biased interpretations of faunal richness, paleoecology, and paleobiogeography. My study suggests little correlation between body size and the representation of individual species in cave versus open-air deposits, but other types of studies focusing on abundance data from individual deposits will provide a better method of analysis (i.e., Muñoz-Durán and Van Valkenburgh, 2006).

The inclusion of cave data is vital to understanding the late Pleistocene geographic distribution of sciurid rodents. In all cases but one, caves either provide fairly good geographic representation for individual species of sciurids when considered as a whole, or they fill gaps in our understanding of the late Pleistocene distribution of sciurids.

The analyses presented here are preliminary although they do provide some insight into the importance of distinct depositional systems for our understanding of the fossil record. Additional research using statistical methods of evaluation might further clarify the contributions to the fossil record made by cave versus non-cave deposits. Analyses that incorporate older deposits would also be of interest. There are also suites of behavioral characteristics of individual species (e.g., diurnal vs. nocturnal) that might correlate with their preservation potential in cave versus non-cave deposits.

Table 5. Cave representation data for all taxa. Taxa listed as having 'low' or 'high' representation in the fossil record of caves had individual *C/T* values either lower than or higher than C/T_{all} ± one standard deviation. C/T_{all} = 0.624 with a *SD* = 0.244. Threshold values were 0.380 for low representation and 0.868 for high.

Taxon	*C*	*T*	*C/T*	Category
Didelphis virginiana	7	16	0.438	Moderate
Dasypus bellus	12	21	0.571	Moderate
Holmesina septentrionalis	2	12	0.167	Low
Megalonyx jeffersonii	8	21	0.381	Moderate
Nothrotheriops shastensis	12	17	0.706	Moderate
Glossotherium harlani	1	21	0.048	Low
Blarina sp.	26	43	0.605	Moderate
Cryptotis parva	18	25	0.720	Moderate
Notiosorex crawfordi	13	18	0.722	Moderate
Sorex arcticus	12	18	0.667	Moderate
Sorex cinereus	17	30	0.567	Moderate
Sorex dispar	7	7	1.000	High
Sorex fumeus	10	10	1.000	High
Sorex hoyi	15	17	0.882	High
Sorex palustris	13	21	0.619	Moderate
Condylura cristata	10	11	0.909	High
Parascalops breweri	12	12	1.000	High
Scalopus aquaticus	19	36	0.528	Moderate
Eptesicus fuscus	18	19	0.947	High
Myotis velifer	8	8	1.000	High
Pipistrellus subflavus	13	13	1.000	High
Canis dirus	44	78	0.564	Moderate
Canis latrans	24	44	0.545	Moderate
Canis lupus	14	22	0.636	Moderate
Urocyon cinereoargenteus	11	19	0.579	Moderate
Vulpes velox	8	13	0.615	Moderate
Vulpes vulpes	13	17	0.765	Moderate
Puma concolor	11	13	0.846	Moderate
Lynx rufus	20	26	0.769	Moderate
Smilodon spp.	11	29	0.379	Low
Panthera leo atrox	11	23	0.478	Moderate
Panthera onca	12	17	0.706	Moderate
Lontra canadensis	3	8	0.375	Low
Mephitis mephitis	19	27	0.704	Moderate
Spilogale putorius	19	24	0.792	Moderate
Gulo gulo	3	4	0.750	Moderate

Table 5 continued.

Taxon	*C*	*T*	*C/T*	Category
Martes americana	13	15	0.867	Moderate
Martes nobilis	6	7	0.857	Moderate
Martes pennanti	9	12	0.750	Moderate
Mustela erminea	9	10	0.900	High
Mustela frenata	17	23	0.739	Moderate
Mustela nigripes	5	5	1.000	High
Mustela nivalis	11	11	1.000	High
Mustela vison	8	11	0.727	Moderate
Taxidea taxus	18	24	0.750	Moderate
Bassariscus astutus	10	10	1.000	High
Procyon lotor	12	20	0.600	Moderate
Arctodus simus	6	15	0.400	Moderate
Tremarctos floridanus	11	18	0.611	Moderate
Ursus americanus	24	36	0.667	Moderate
Ursus arctos	5	6	0.833	Moderate
Mammuthus columbi	5	83	0.060	Low
Mammuthus jeffersoni	1	54	0.019	Low
Mammuthus primigenius	0	28	0.000	Low
*Mammut americanum**	27	206	0.131	Low
Equus conversidens	16	28	0.571	Moderate
Equus occidentalis	8	20	0.400	Moderate
Tapirus sp.	27	56	0.482	Moderate
Mylohyus sp.	30	46	0.652	Moderate
Platygonus compressus	37	60	0.617	Moderate
Camelops hesternus	12	48	0.250	Low
Hemiauchenia macrocephala	16	27	0.592	Moderate
Palaeolama mirifica	7	14	0.500	Moderate
Cervus elaphus	6	8	0.750	Moderate
Alces alces	3	3	1.000	High
Cervalces scotti	5	35	0.149	Low
Navahoceros fricki	7	9	0.778	Moderate
Odocoileus hemionus	8	14	0.571	Moderate
Odocoileus virginianus	28	56	0.500	Moderate
Rangifer tarandus	9	24	0.375	Low
Antilocapra americana	15	28	0.536	Moderate
Capromeryx minor	2	6	0.333	Low
Bison bison	9	53	0.170	Low
Bootherium bombifrons	11	102	0.108	Low
Oreamnos harringtoni	5	9	0.556	Moderate
Ovis canadensis	18	21	0.857	Moderate

Table 5 continued.

Taxon	*C*	*T*	*C/T*	Category
Ammospermophilus leucurus	4	6	0.667	Moderate
Cynomys leucurus	1	3	0.333	Low
Cynomys ludovicianus	9	26	0.347	Low
Marmota flaviventris	27	30	0.900	High
Marmota monax	14	17	0.824	Moderate
Sciurus carolinensis	8	12	0.667	Moderate
Sciurus niger	6	10	0.600	Moderate
Spermophilus franklini	0	8	0.000	Low
Spermophilus lateralis	8	10	0.800	Moderate
Spermophilus richardsonii	5	14	0.357	Low
Spermophilus spilosoma	1	2	0.500	Moderate
Spermophilus townsendii	4	7	0.571	Moderate
Spermophilus tridecemlineatus	17	32	0.531	Moderate
Spermophilus variegatus	9	10	0.900	High
Tamias minimus	9	13	0.692	Moderate
Tamias striatus	15	20	0.750	Moderate
Tamiasciurus hudsonicus	15	19	0.789	Moderate
Glaucomys sabrinus	7	7	1.000	High
Glaucomys volans	13	15	0.867	Moderate
Castor canadensis	10	23	0.435	Moderate
Castoroides ohioensis	4	34	0.118	Low
Geomys bursarius	9	26	0.346	Low
Geomys pinetis	4	8	0.500	Moderate
Pappogeomys castanops	5	5	1.000	High
Thomomys bottae	10	20	0.500	Moderate
Thomomys talpoides	10	27	0.370	Low
Dipodomys ordii	5	8	0.625	Moderate
Chaetodipus hispidus	7	12	0.583	Moderate
Perognathus parvus	2	4	0.500	Moderate
Napeozapus insignis	10	11	0.909	High
Zapus hudsonius	13	18	0.722	Moderate
Zapus princeps	2	4	0.500	Moderate
Clethrionomys gapperi	18	25	0.720	Moderate
Dicrostonyx torquatus	7	8	0.875	High
Lemmiscus curtatus	13	17	0.765	Moderate
Microtus chrottorrhinus	7	7	1.000	High
Microtus longicaudus	7	11	0.636	Moderate
Microtus mexicanus	6	7	0.857	Moderate
Microtus montanus	7	11	0.636	Moderate
Microtus ochrogaster	9	20	0.450	Moderate

Table 5 continued.

Taxon	*C*	*T*	*C/T*	Category
Microtus pennsylvanicus	24	55	0.436	Moderate
Microtus pinetorum	17	22	0.773	Moderate
Microtus xanthognathus	12	18	0.667	Moderate
Neofiber alleni	3	11	0.273	Low
Ondatra zibethicus	19	50	0.380	Moderate
Phenacomys intermedius	22	28	0.786	Moderate
Synaptomys borealis	17	20	0.850	Moderate
Synaptomys cooperi	20	36	0.556	Moderate
Baiomys taylori	2	2	1.000	High
Neotoma albigula	7	10	0.700	Moderate
Neotoma cinerea	19	23	0.826	Moderate
Neotoma floridana	19	27	0.704	Moderate
Neotoma lepida	9	18	0.500	Moderate
Neotoma mexicana	5	5	1.000	High
Netoma micropus	4	7	0.571	Moderate
Onychomys leucogaster	5	15	0.333	Low
Oryzomys palustris	6	13	0.462	Moderate
Peromyscus leucopus	10	17	0.588	Moderate
Peromyscus maniculatus	15	26	0.577	Moderate
Reithrodontomys megalotis	2	6	0.333	Low
Sigmodon hispidus	14	27	0.519	Moderate
Erethizon dorsatum	26	29	0.897	High
Ochotona princeps	18	24	0.750	Moderate
Brachylagus idahoensis	4	6	0.667	Moderate
Lepus americanus	7	8	0.875	High
Lepus californicus	14	20	0.700	Moderate
Lepus townsendii	4	7	0.571	Moderate
Sylvilagus audubonii	7	12	0.583	Moderate
Sylvilagus floridanus	7	12	0.583	Moderate
Sylvilagus nuttallii	7	8	0.875	High

Table 6. Summary data for comparisons of mammalian orders (e.g., $C/T_{Rodentia}$). n = number of taxa considered in this study for a particular order. SD = Standard Deviation.

Taxa	n	C/T_{group}	SD	High	Low
Marsupialia	1	0.438	-	-	-
Xenarthra	5	0.375	0.273	0.648	0.102
Insectivora	12	0.768	0.180	0.948	0.588
Chiroptera	3	0.982	0.030	1.000	0.952
Carnivora	30	0.707	0.172	0.879	0.535
Proboscidea	4	0.052	0.058	0.110	0.000
Perissodactyla	3	0.485	0.086	0.571	0.399
Artiodactyla	18	0.516	0.250	0.766	0.266
Rodentia	62	0.627	0.227	0.854	0.400
Lagomorpha	8	0.701	0.125	0.826	0.576

Table 7. The representation of 'montane' taxa in Pleistocene cave deposits in the United States versus Holocene cave deposits in the United States. (##) = sample size.

Taxon	Pleistocene	Holocene
Neotoma cinerea	0.826 (23)	0.674 (43)
Spermophilus lateralis	0.800 (10)	0.467 (15)
Microtus longicaudus	0.636 (11)	0.538 (13)
Sylvilagus nuttallii	0.875 (8)	0.315 (54)
Marmota flaviventris	0.900 (30)	0.440 (75)
Sorex palustris	0.619 (21)	0.833 (6)
Lepus townsendii	0.571 (7)	0.103 (43)
Mustela erminea	0.900 (10)	0.000 (3)
Ochotona princeps	0.750 (24)	0.600 (10)
Zapus princeps	0.500 (4)	1.000 (4)
Gulo gulo	0.750 (4)	0.571 (7)

Table 8. Correlation (R^2) values for comparisons of minimum body mass versus cave representation values. n = number of taxa included. Data for individual species are listed by taxonomic group in Appendix 2.

Taxonomic Group	n	R^2 value
All Taxa	113	0.006
Insectivora	12	0.044
Carnivora	23	0.000
Artiodactyla	8	0.010
Rodentia	57	0.004
Lagomorpha	8	0.151

Table 9. Correlation (R^2) values for comparisons of maximum body mass versus cave representation values. n = number of taxa included. Data for individual species are listed by taxonomic group in Appendix 2.

Taxonomic Group	n	R^2 value
All Taxa	115	0.004
Insectivora	12	0.023
Carnivora	24	0.000
Artiodactyla	8	0.020
Rodentia	58	0.000
Lagomorpha	8	0.081

A

B

Figure 9. Photos of miscellaneous bone samples from Cathedral Cave, Nevada (A), and individual vials containing a sub-sample of isolated rodent teeth from the site (B).

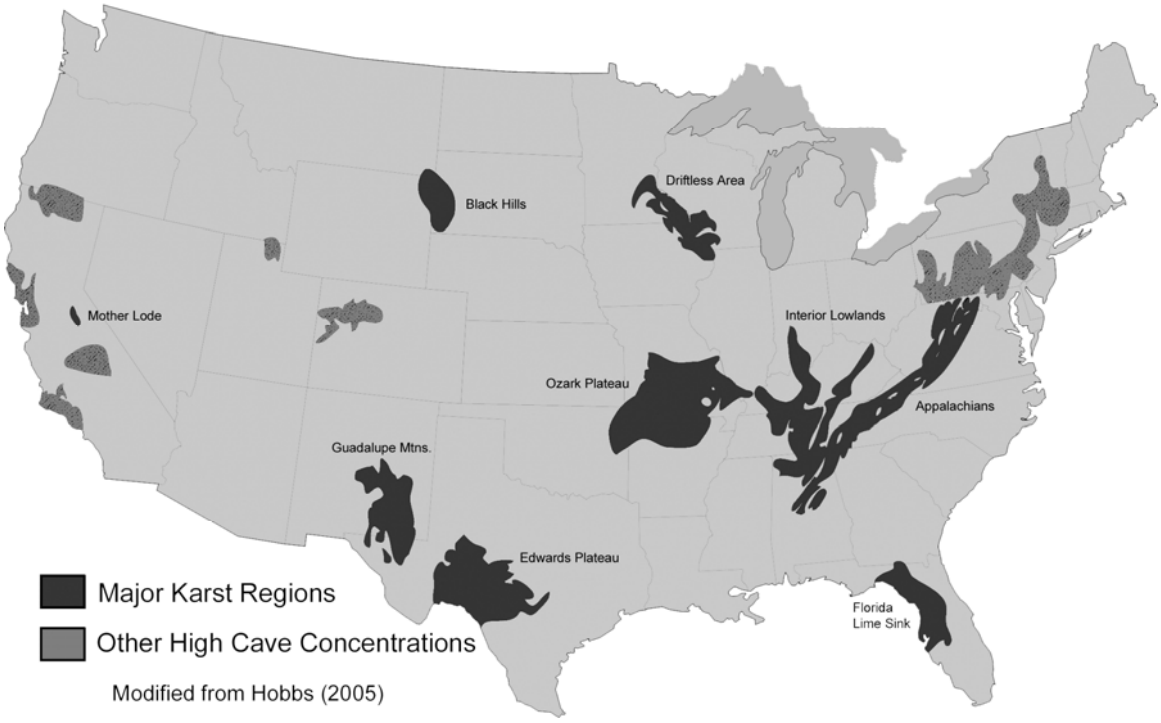


Figure 10. Distribution of areas with karst topography and areas with a high density of cave deposits. Modified from Hobbs (2005).

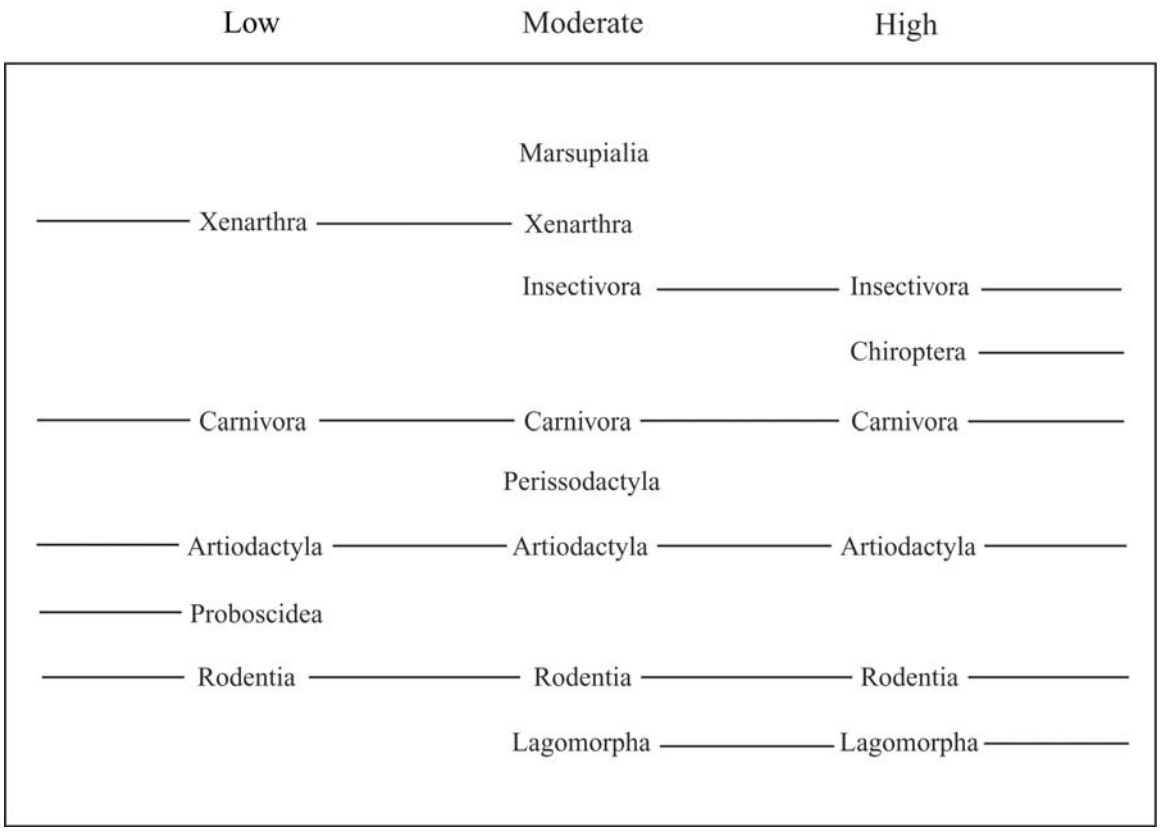


Figure 11. The distribution of taxonomic groups across cave representation categories. Threshold *C/T* values were 0.380 for low representation and 0.868 for high.

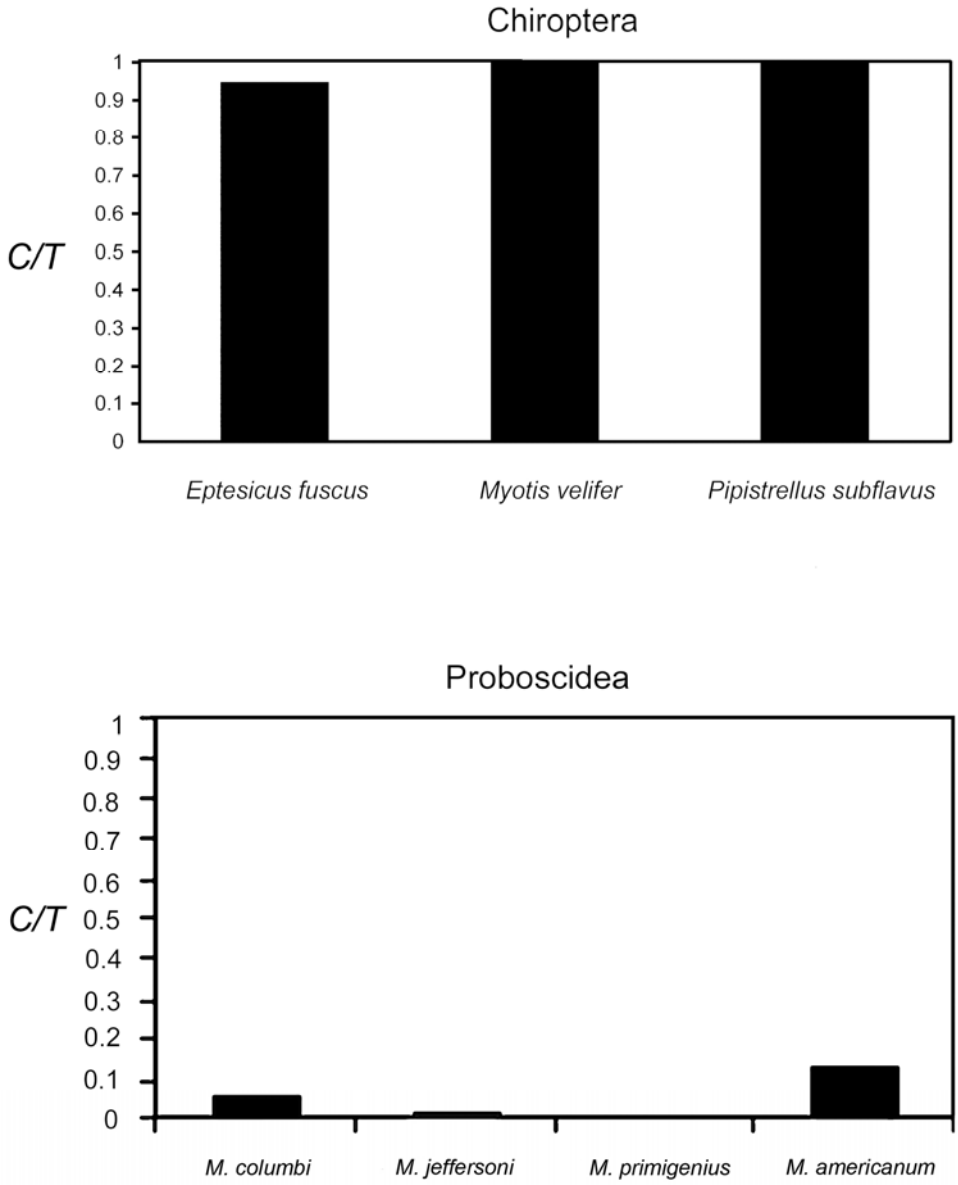
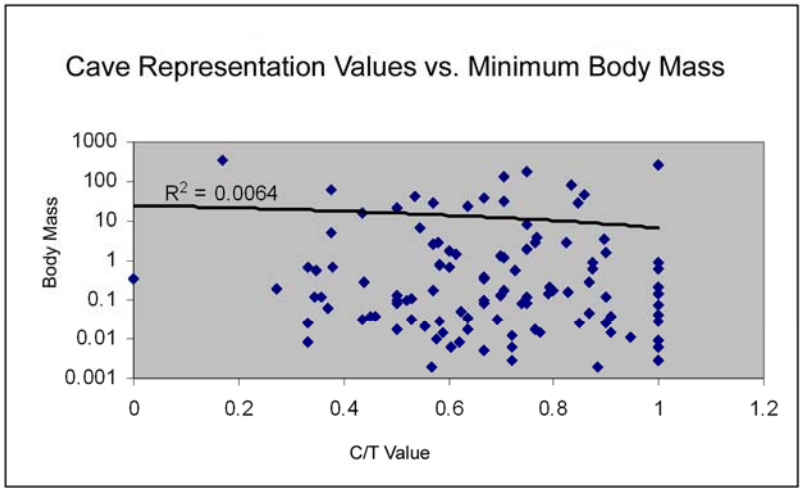


Figure 12. Histograms showing the cave representation values of chiropterans and proboscideans. *M. columbi*, *M. jeffersoni*, and *M. primigenius* are species of *Mammuthus*. *M. americanum* is a species of *Mammut*.

A



B

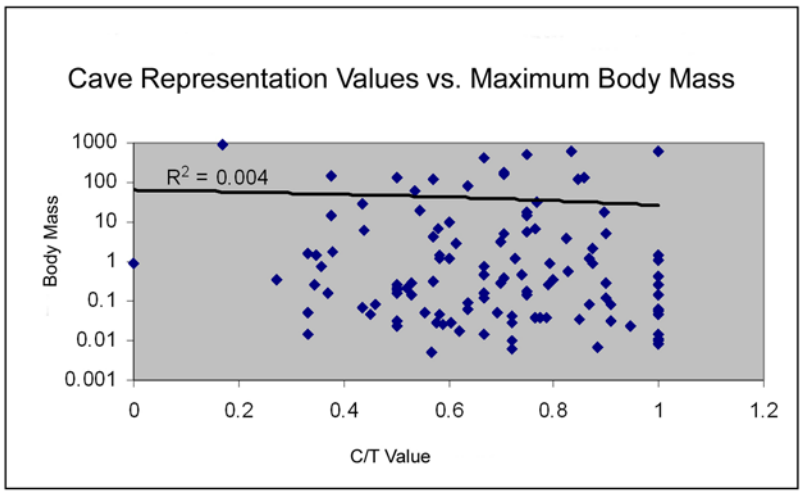


Figure 13. Scatterplots showing the relationship between *C/T* values and body mass. A. *C/T* values versus minimum body mass; n = 113. B. *C/T* values versus maximum body mass; n =114. In the figures, body mass is presented on a logarithmic scale.

Figure 14. The late Pleistocene geographic distribution of *Ammospermophilus leucurus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 15. The late Pleistocene geographic distribution of *Cynomys leucurus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 16. The late Pleistocene geographic distribution of *Cynomys ludovicianus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

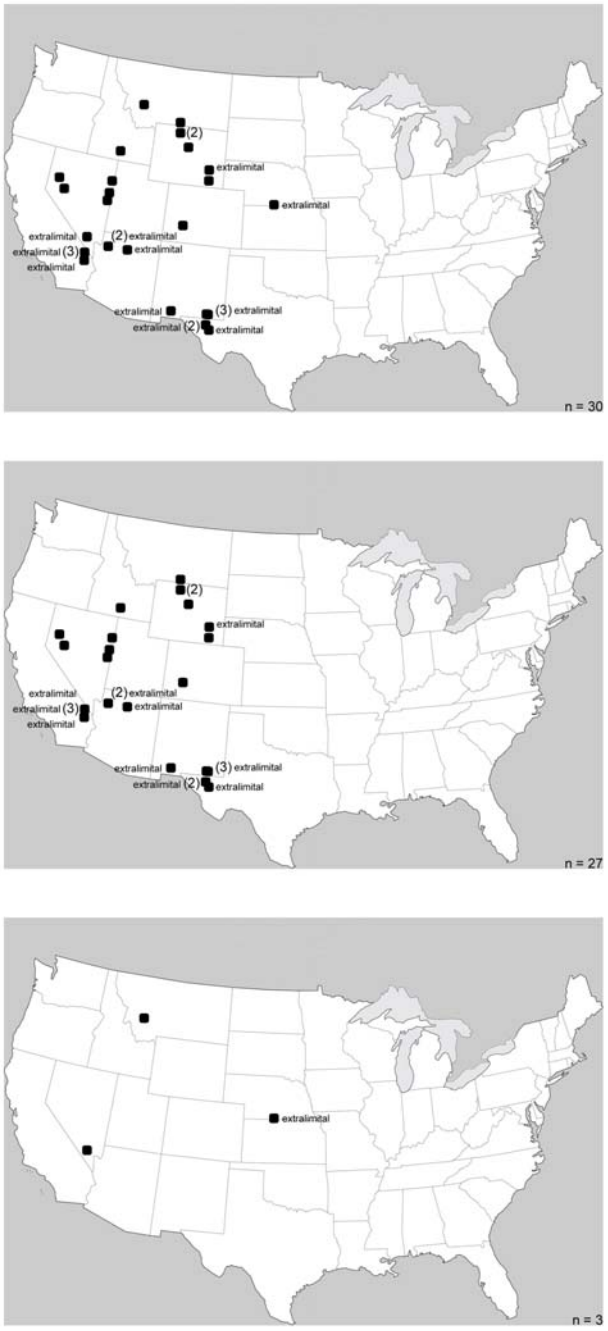


Figure 17. The late Pleistocene geographic distribution of *Marmota flaviventris* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 18. The late Pleistocene geographic distribution of *Marmota monax* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 19. The late Pleistocene geographic distribution of *Spermophilus franklini* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 20. The late Pleistocene geographic distribution of *Spermophilus lateralis* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 21. The late Pleistocene geographic distribution of *Spermophilus richardsonii* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 22. The late Pleistocene geographic distribution of *Spermophilus spilosoma* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 23. The late Pleistocene geographic distribution of *Spermophilus townsendii* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 24. The late Pleistocene geographic distribution of *Spermophilus tridecemlineatus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 25. The late Pleistocene geographic distribution of *Spermophilus variegatus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 26. The late Pleistocene geographic distribution of *Sciurus carolinensis* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 27. The late Pleistocene geographic distribution of *Sciurus niger* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 28. The late Pleistocene geographic distribution of *Tamias minimus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 29. The late Pleistocene geographic distribution of *Tamias striatus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 30. The late Pleistocene geographic distribution of *Tamiasciurus hudsonicus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 31. The late Pleistocene geographic distribution of *Glaucomys sabrinus* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

Figure 32. The late Pleistocene geographic distribution of *Glaucomys volans* based on all records (top), cave records (middle), and non-cave records (bottom). Data from FAUNMAP Working Group (1994).

CHAPTER 3: PLEISTOCENE BIOCHRONOLOGY AND PROVINCIALITY IN THE EAST-CENTRAL GREAT BASIN

INTRODUCTION

Over the past 100 years, a significant amount of research was dedicated to the use of mammalian fossils as time markers (mammalian biochronology) for broad regions of North America. The initial understanding of the stratigraphic and chronologic relationship between terrestrial deposits of Cenozoic age in North America relied heavily on the known distribution of mammalian fossils across sedimentary horizons. Subsequent discovery of independent dating methods (e.g., radioisotopes, paleomagnetics) allowed relative correlations to be tested, refined, and revised in the context of a numeric age assessment. However, the use of mammalian fossils as chronologic markers remains a vital aspect of paleontological research because external age control is not always available in fossiliferous sedimentary sequences. Early studies at Cathedral Cave, Nevada, resulted in a unique dilemma where biochronologic age estimates conflicted with radioisotopic data (Bell, 1995; Bell and Barnosky, 2000). In this chapter I present the results of a hypothesis-based study designed to resolve that chronological dilemma. I compare the results of my study with of our current understanding of biochronologic data for the Pleistocene of North America, and discuss the implications of the Cathedral Cave fauna for biochronologic provinciality in the Great Basin of the western United States.

MAMMALIAN BIOCHRONOLOGY AND THE PLEISTOCENE

The use of mammalian fossils for the correlation of terrestrial deposits has been of interest to vertebrate paleontologists for over 100 years (e.g., Cope, 1883; Marsh, 1891; Osborn, 1909) and remains an important aspect of paleontological research (e.g., Woodburne, 1987a, b, 2004). The explicit use of mammalian fossils as relative time-markers was codified in 1941 with the publication of a mammalian biostratigraphy by the Wood Committee (Wood et al., 1941). The intent of the Wood Committee was to use characteristic groups of mammals, whose temporal distribution and stage of evolution were thought to represent a discrete time interval, as a basis for subdividing the Cenozoic into a relative time scale (Woodburne, 1987a). These biochronologic subdivisions were named 'Land Mammal Ages' (LMAs) and dealt exclusively with Tertiary deposits (Wood et al., 1941).

The Pleistocene, or rather the Quaternary of North America as a whole, remained undifferentiated by LMAs until 1951, when Donald Savage proposed two new LMAs. The Irvington fauna of northern California was proposed as representative of the Irvingtonian LMA, and the fauna from the tar pits at Rancho la Brea, CA were proposed as characteristic of the Rancholabrean LMA (Savage, 1951). The first appearance of *Bison* was used to define the Rancholabrean and its absence was used to recognize the Irvingtonian (Savage, 1951). Despite attempts to clarify the faunal divisions between the Irvingtonian and Rancholabrean (e.g., Lundelius et al., 1987), this usage persisted until recently.

Recent work by Bell et al. (2004b) represented an explicit attempt to clarify and summarize the spatial and stratigraphic distribution of Pleistocene mammals within an integrated chronologic framework. The taxa used to define and characterize each LMA emphasized earliest known records of widely dispersed mammals that were associated with reliable forms of external age control (see Table 10; Bell et al., 2004b). Because it is unlikely that taxa disperse completely across a continent at a uniform rate, Bell et al. (2004b) specifically chose defining taxa that would minimize the time-transgressive nature of the Irvingtonian-Rancholabrean boundary for much of North America. Recognition of the probability that diachronous biochronologic boundaries (i.e., provincialism) represent the norm rather than the exception was noted in previous studies dealing with Plio-Pleistocene biochronology (e.g., Repenning, 1987; Fejfar and Repenning, 1992), and explicitly acknowledged by Bell et al. (2004b). The latter portion of the Blancan LMA, all of the Irvingtonian, and most of the Rancholabrean are recognized as contemporaneous with the Pleistocene (1.77 ma to 9.5 ka; Bell et al., 2004b).

Early research concerning the timing of immigration, dispersal, evolution, and extinction of species of arvicoline rodents expanded our ability to correlate terrestrial deposits and improved the temporal refinement of North American mammalian biochronology (e.g., Repenning, 1978, 1984, 1987, 1998; Martin, 1979). Arvicoline rodents are known to occur in a wide array of environmental settings, they have a broad geographic distribution, and they reproduce and disperse rapidly, all of which contribute to their utility as biochronologic markers. Recent biochronologic summaries continued to place importance on arvicoline rodents as potentially defining and characteristic taxa for

the Blancan, Irvingtonian, and Rancholabrean LMAs (see Table 10; Bell, 2000; Martin, 2003; Bell et al., 2004b).

PLEISTOCENE BIOCHRONOLOGY IN THE GREAT BASIN

The Great Basin of the western United States is a broad geographic region characterized by horst and graben topography where isolated mountain ranges are separated by relatively narrow, low-lying valleys (Grayson, 1993). The region has documented biogeographic complexities associated with diverse topography, mammalian distributions, and climatic shifts (e.g., Brown, 1971, 1978; Grayson and Livingston, 1993; Lomolino and Davis, 1997; Grayson, 2000a) that suggest the potential for the recognition of complex, provincial biochronologic patterns. Much paleontological research in the region focused on cave deposits containing faunal remains associated with archeological materials. As a result, there is considerable regional data for Pleistocene and Holocene deposits that fall within the range of radiocarbon dating. Paleontological sites of Pleistocene age that are older than 30,000 yr B. P. are rare and lack reliable external age control. Hence, the development of a biochronologic framework for the Pleistocene of the Great Basin is at an early stage.

Blancan deposits are known from the region but most of these either pre-date the Pleistocene (e.g., the Panaca Formation; Lindsay et al., 2002) or lack independent age control (e.g., Sunrise Pass Formation; Kelly, 1994; Trexler et al., 2000; summary by Bell et al., 2004b). Only the Topaz Lake Fauna from Douglas County, NV contains

mammalian fossils that likely fall within the portion of the Blancan LMA that extends into the early Pleistocene (Kelly, 1997; Bell et al., 2004b).

Mammal-bearing deposits indicative of the Irvingtonian LMA are also rare in the Great Basin. In their recent summary, Bell et al. (2004b) indicated that Cathedral Cave, Nevada, represented the sole known mammal-bearing locality of Irvingtonian age from the Great Basin. However, conflicting evidence for the age of Cathedral Cave necessitated the study presented here.

The record of Rancholabrean faunas in the Great Basin is restricted to a time range from 30,000 yr B. P. to 9500 yr B. P. The faunal history for earlier portions of the Rancholabrean of Great Basin is unknown. There is a possibility that this accurately reflects preservation in the fossil record of the Great Basin, but it seems likely that a focus on deposits of more recent age (i.e., archeological sites) is driving this phenomenon.

Because of the paucity of data on Irvingtonian and pre-radiocarbon Rancholabrean faunas of the Great Basin, any sites that fall within that time frame will be biochronologically informative. Cathedral Cave, Nevada, is such a site, but issues with the age control of the initial test pit excavations needed to be addressed. With that objective in mind, I re-opened field investigations at Cathedral Cave in 2003.

A CHRONOLOGIC CONUNDRUM

Cathedral Cave (CC) is located on a north-facing slope at the mouth of Smith Creek Canyon in eastern Nevada. The geographic location of the site places it within the east-central portion of the Great Basin. Preliminary fieldwork at the site was conducted

in 1989 and was intended to test the paleontological significance of the site (Bell, 1990). The initial excavation consisted of the removal of two contiguous 1x1 m test pits in 10-cm levels (Bell, 1990). These test pits, named CC 89-1 and CC 89-2, were excavated to depths of 45 cm and 90 cm below datum (cmbd), respectively. Over 10,000 identifiable vertebrate specimens were recovered in the 1989 excavation suggesting that the potential for paleontological research at the site was high.

Initial age estimates for the site were based on two bulk uranium-series dates (U-series; Bell, 1990). The first sample consisted of a piece of an isolated flowstone/stalagmite from the third level of CC 89-1 and had a measured $^{230}Th/^{234}U$ age of 15,000 ± 200 yr B.P. (Bell, 1990). The second sample consisted of an ungulate bone fragment from the lowest level of CC 89-2 and had a $^{231}Pa/^{235}U$ age of 24,600 ± 2100 yr B.P. and a $^{230}Th/^{234}U$ age of 24,400 ± 2000 yr B.P. (Bell, 1990). These age data were stratigraphically sound and were chronologically consistent with other cave deposits in Smith Creek Canyon.

Potential problems with the initial age estimates for the Cathedral Cave fauna were identified when the assemblage of arvicoline rodents was re-analyzed (Bell, 1995). Re-analysis of the arvicoline rodent fauna from Cathedral Cave suggested a significantly older age for the excavated portion of the deposit. The revised age placed the age of excavated sediments from the 1989 excavation between 750 ka and 850 ka (Bell and Barnosky, 2000). This age range was based on the known chronologic distribution of arvicoline rodent taxa recovered in the excavation and the overall similarity of the CC arvicoline fauna to that from the Pit locality in Porcupine Cave, Colorado. Cathedral

Cave and the Pit locality had nearly identical arvicoline faunas, the only exception being the absence of the muskrat genus *Ondatra* at CC. Additionally, the Pit locality had independent paleomagnetic data that supported an age placement between 750 ka and 850 ka (i.e., magnetically reversed sediments within the sedimentary sequence; Bell and Barnosky, 2000).

The biochronologic placement for Cathedral Cave created something of dilemma in that the age estimate differed from the dates derived from uranium-series analyses by approximately 725,000 years. This discrepancy suggested four mutually exclusive explanations. First, Cathedral Cave might preserve a late Pleistocene arvicoline rodent fauna unlike any other from the Great Basin or other regions of North America. Second, Cathedral Cave might preserve a fauna of middle Pleistocene age, and was providing unique insight into a time frame for which there is little available data in the Great Basin. Third, it was possible that neither of the previous age estimates was accurate. Finally, it was possible that Cathedral Cave contained stratigraphically mixed sediments that span portions of the last 750,000 years. I began my work at Cathedral Cave with the hypothesis that the biochronologic age estimate for Cathedral Cave was accurate for at least some portions of the deposit. I chose this as a working hypothesis because of the strong similarity between arvicoline faunas from CC and the Pit locality and because there was no indication of stratigraphically mixed sediments (Bell, 1990).

METHODS AND MATERIALS

In order to test the correctness of the biochronologic age assignment for CC, a new excavation was required. The primary reasons for a new excavation were to

excavate at finer stratigraphic intervals with careful attention to potential post-depositional mixing or disturbance of the sediments, to collect materials that could be radioisotopically dated, to collect samples of undisturbed sediments for paleomagnetic analysis, and to attempt to recover additional arvicoline rodent fossils. Because this undertaking included multiple methods related to both the field and laboratory aspects of the research, I discuss each research area individually below.

Excavation, Screen-Washing, and Sorting

In 2003 I revisited CC and excavated an area slightly to the east of the 1989 excavation. I had originally planned to excavate the area directly adjacent to the 1989 excavation but disturbance of the 1989 backfill rendered that plan impractical. Instead, a 2 x 3 m grid was laid out in which the western-most squares roughly corresponded to the 1989 excavation, and the 2003 excavation consisted of the eastern 1.5 x 2 m of the grid (Figs. 2, 4). The new excavation was conducted at 5-cm levels except in areas where natural sedimentary layers were removed as discrete samples. These detailed excavation methods were utilized specifically to explore the possibility that the sediments were stratigraphically mixed and to determine if the faunal assemblage described by Bell was an artifact of coarser sampling (i.e., 10-cm levels). Ultimately, over 100 individual fossils were hand collected as the excavation proceeded and 226 bags (1 to 2 gallons in size) of matrix were collected for screen-washing/sorting. More specific details of the excavation and laboratory procedures are outlined in Chapter 1.

Screen-washing through nested pairs of screens (3.175 mm and 0.7 mm-mesh) resulted in 450 bags of concentrate (226 coarse, 226 fine). The sample of arvicoline

rodent fossils presented below was derived from the sorting of 226 bags of coarse mesh (3.175 mm) sediment and single bags of fine mesh sediments (0.7 mm) from each unique sedimentary level. Sorting efforts focused more heavily on the coarser matrix because of a higher abundance of lower first molars (m1) of arvicoline rodents in those sediments. All sorting was conducted under a binocular microscope (minimum 10x magnification) and each recovered specimen was placed in an individual vial and assigned a unique specimen number. Specimens are curated at the Vertebrate Paleontology Laboratory of the Texas Memorial Museum (TMM) under the locality number 43693 (e.g., TMM 43693-1, etc.). The other institutional abbreviation mentioned below is for specimens from the United States National Museum (USNM).

Flowstone Samples and Radioisotopic Analyses

Uranium-series ages are derived from the evaluation of decay rates of ^{238}U and ^{235}U into a series of daughter products. In ancient (~10^6 yr), undisturbed systems containing uranium, an equilibrium state occurs whereby individual daughter products decay at the same rate at which they are produced by the parent isotope (Broecker and Bender, 1972). Ratios of each isotope in the decay chain are constant and disturbances or deviations from this equilibrium state allow for estimates of elapsed time (Ivanovich and Harmon, 1982; Bradley, 1999). Specific portions of the uranium-series decay chain are important for the dating of Quaternary cave deposits (e.g., $^{230}Th/^{234}U$; $^{231}Pa/^{235}U$). The utility of $^{230}Th/^{234}U$ and $^{231}Pa/^{235}U$ systems for the dating of cave deposits is in part the result of both ^{230}Th and ^{231}Pa being insoluble in water (Bradley, 1999). Unlike uranium, which precipitates with calcite from water, these isotopes are initially absent or minor

constituents of speleothems (Bradley, 1999). Thus, measured amounts of ^{230}Th and ^{231}Pa in speleothems are a function of the initial amount of uranium in a given speleothem as well as time (Bradley, 1999).

Potential problems with the measurement of ^{230}Th and ^{231}Pa within speleothems include the assumption of initial isotopic ratios (e.g., ^{230}Th/^{234}U), the question of whether speleothems are completely closed systems, and the incorporation of detrital daughter products into speleothems (Bradley, 1999). The nature of early samples submitted for uranium-series dates from CC (an ungulate bone fragment and a buried stalagmite that was crushed whole with no cleaning) are problematic, particularly with respect to open-system behavior and detrital contamination.

The chance of open system behavior in these samples was possibly a more significant problem, especially considering the contrast in uranium-series ages and the biochronologic age assessment for CC. There is some evidence that bone exchanges uranium post-depositionally, thereby minimizing the reliability of both the ^{230}Th/^{234}U and ^{231}Pa/^{235}U ages derived from the ungulate bone fragment (see discussion in Bradley, 1999).

The age of the stalagmite sample is possibly less problematic, but the use of a bulk sample meant that any portion of the stalagmite that may have exhibited open system behavior (e.g., recrystallization) was part of the sample. However, incorporation of detrital ^{230}Th into these samples during crystallization seems unlikely given the relatively young ages. Inclusion of detrital materials within calcite potentially adds ^{230}Th thereby yielding an older-than-actual age (Schwarcz and Latham, 1989). Stalagmites often form in discrete, chronologically-differentiated layers, and the bulk sample likely

contained material of different ages. Inclusion of matrix adhering to the stalagmite in the bulk sample increased the potential age range incorporated into the bulk sample (C. J. Bell, personal communication).

Because of the possibility that previous U-series dates did not provide a reliable chronologic context for fossils excavated from the site, additional work was warranted. One of the primary goals of conducting additional fieldwork at CC was to recover radioisotopically datable materials (e.g., speleothems) in direct association with diagnostic arvicoline rodent fossils. During the 2003 fieldwork at CC I was able to collect three samples of *in situ* flowstone from two different areas of the excavation. The first sample was collected at a depth of 79 cmbd from a flowstone in the SE corner of excavation square 1N 3E (Fig. 4). The second and third samples came from an *in situ* flowstone in the NE corner of excavation square 2N 3E (Fig. 4). Sample 2 was collected from the 90-95 cmbd excavation level and sample 3 was collected from a depth of 91.5 cmbd. All three samples came from flowstones that formed part of the excavation wall. In the case of samples 2 and 3, the flowstone nearly filled the excavation square at a depth of 102 cmbd. In both cases the flowstone sloped into the excavated area, suggesting that these speleothems must have been emplaced prior to the deposition of the majority of excavated sediments. As a result, ages derived from the flowstone samples represent the maximum for fossils collected from the eastern-most excavation squares, at least.

Flowstone samples were inspected at The University of Texas at Austin (UT-Austin) where it was determined that only sample 3 was likely to produce a reliable age. Samples 1 and 2 had distinct layering but none of the individual layers were clear,

suggesting that they might contain high amounts of detrital materials. Sample 3 had some individual layers that were clearer than layers from samples 1 and 2, but even those were not pristine. I focused my sub-sampling of sample 3 on the clearest layers and traced them as far as possible. Multiple discrete layers were sampled in order to obtain sufficient amounts of carbonate (1.0 g per sample) for three separate U-series analyses (Fig. 33).

Initial preparation of sample 3 for subsampling followed an eight-step cleaning procedure intended to eliminate potential contaminants from the flowstone. These included scrubbing the flowstone with a clean toothbrush using distilled water, scrubbing 'micro' (i.e., soap) over the flowstone with a toothbrush, rinsing the specimen with distilled water, placing of the sample in a bath of distilled water in a running sonic cleanser for five minutes, rinsing with de-ionized water, placing of the sample in a bath of de-ionized water in a running sonic cleanser for five minutes, rinsing with de-ionized water, and air drying under a clean-air hood.

The 1.0 g sub-samples were obtained by drilling the flowstone using a dental drill with an inserted Brasseler carbide shank II. All drilling was conducted under a clean-air hood and over weighing paper. Prior to drilling the samples, the carbide shank was dipped in nitric acid, inserted into de-ionized water and then ethanol. The drill was then turned on to remove any unevaporated water from the shank. As portions of the flowstone were drilled, a clean, sterile, dental pick was used to gently scrape the powdered flowstone matrix onto weighing paper. Periodically, the powdered flowstone was transferred into a clean glass vial and just over 1.0 grams was obtained for each of

the sub-samples. Two subsamples were submitted for radioisotopic age analyses at UT-Austin and one was sent to the University of Minnesota.

Samples for Paleomagnetic Analyses

The previous biochronologic age estimate for CC (750,000 ka to 850,000) placed the locality within a chronologic framework that suggested the collection of samples for paleomagnetic analyses might be useful for further age assessment. The utility of paleomagnetic analyses for relative dating of geological deposits (magnetostratigraphy) results from the fact that the position of Earth's magnetic pole exhibits both minor and major fluctuations through time (Opdyke and Channell, 1996). Complete reversals in the Earth's magnetic field are preserved in the rock record and form the basis of magnetostratigraphy (Opdyke and Channell, 1996).

Normal (i.e., the orientation of the magnetic field observed today) and reversed polarity states are used to form a relative chronologic framework that is anchored to a numeric time-scale through the use of independent radioisotopic dating (Opdyke and Channell, 1996). Because the Global Polarity Time Scale (GPTS) is applicable worldwide, the use of paleomagnetic data from terrestrial sequences provides an important tool for the refinement and correlation of terrestrial deposits and the mammalian fossil assemblages that they sometimes contain.

For the Pleistocene, two major geomagnetic polarity chrons are recognized including the Matuyama Chron (2.58 ma to 780 ka) and the Brunhes Chron (780 ka to modern; Berggren et al., 1995). The most recent age estimates for CC were placed between 750 ka and 850 ka based on the faunal similarity to the Pit locality in Porcupine

Cave, and paleomagnetic data from that site (Bell and Barnosky, 2000). Given this age estimate, CC sediments potentially preserved both normal and reversed magnetic signals. The presence of sediments recording a normal magnetic signal would neither support nor contradict the biochronologic age estimate, but the presence of sediments recording a reversal would provide independent support for that age assignment.

Paleomagnetic sample collection was attempted for both uncemented and cemented sediments. Uncemented sediments were separately immersed with mixtures of sodium silicate and diluted Elmer's glue as consolidants in an attempt to remove oriented samples of appropriate size (1 inch cubed). A layer of cemented sediments was encountered during the course of the excavation ranging variably from 45-60 cmbd across much of a 1 x 2 m area. Cemented samples were removed as a single large, oriented block. The orientation of the block was taken by gluing a thinly-sliced cross-section of a wooden dowel to the surface of the *in situ* block. A strike and dip measurement was taken and recorded on the surface of the wooden dowel using a Brunton compass (azimuth; with the declination set at 0°). Strike was 192° and dip was 3° E-SE.

In the laboratory, the block of cemented sediments was cut into four individual cubes where orientation of the cubes was maintained relative to the field sample. In order to evaluate the potential of the sample cubes for producing viable paleomagnetic data, two separate samples from the sediment block were used for isothermal remnant magnetization (IRM) study. This analysis allows verification and identification of the presence of specific magnetic minerals in a given sample. Remnant magnetism of the

sample was measured and recorded following a series demagnetization and remagnetization steps.

The cubed samples were then evaluated for natural remnant magnetism (NRM) following alternating field (AF) demagnetization procedures. Measurements of the intensity of the magnetic field of each cube were taken in three orthogonal directions after each demagnetization step. All analytical procedures were performed at the Paleomagnetics Laboratory at The University of Texas at Austin.

Fossil Sample and Specimen Identification

A total of 844 m1s of arvicoline rodents make up the sample analyzed here. Identification efforts focused on the lower first molars because they represent one of the most diagnostic teeth in the dentition of arvicoline rodents. Upper third molars can also be diagnostic, but smaller size meant that these teeth were not as common as the m1s in the coarse concentrate. Species identifications were based on comparisons with the dentition of extant and extinct arvicolines, and descriptions and illustrations of those taxa from the literature.

Dental terminology discussed here and depicted in figure 34 follows Bell and Jass (2004). The lower first molar of arvicoline rodents includes a posterior loop, a series of alternating, enamel triangles, and an anterior cap (Fig. 34). The m1 may be rooted or unrooted. Individual triangles are numbered sequentially from posterior to anterior. In the text below, discussions concerning individual triangles use abbreviated references (e.g., the first triangle is referred to as T1, the second as T2, and so forth). The labial and lingual invaginations between triangles are referred to as re-entrant angles and they may

or may not contain cementum. On the illustrations, enamel bands are shown in white, dentine is in black, and cementum is stippled. Broken or missing portions of the teeth are depicted with a series of diagonal lines.

An important character used in the identification of arvicoline rodent fossils includes the relative closure or openness of individual triangles (Fig. 35). For this study, the relative closure of triangles was categorized as being open, pinched, exhibiting incipient closure, or closed. Categorical placement was determined using enamel band-widths following Bell and Barnosky (2000). Open triangles had openings greater than 3 enamel band-widths, pinched triangles had openings between 2 and 3 enamel band-widths, triangles with incipient closure had openings between 1 and 2 enamel band-widths, and closed triangles had openings of less than 1 enamel band width. On unrooted teeth, the relative closure of triangles was evaluated on both occlusal and ventral surfaces in order to account for potential ontogenetic differences.

RESULTS

New excavations at CC resulted in the recovery of approximately 30,000 new identifiable specimens, consisting mostly of isolated teeth. Several new taxonomic records for the cave were recovered including extinct rabbit (*Aztlanolagus*), a large felid, and parts of the skeleton of *Oreamnos harringtoni*. One of the most promising aspects of the new investigations at CC was the identification of a discrete, cemented layer of sediment. The exact timing of deposition for the cementing minerals is uncertain (Osborne, 2004), but if the cement was emplaced at or near the time of sediment deposition it seems unlikely that any sediments occurring below the cemented level

would be mixed with sediments above the cemented level. This, combined with the absence of any evidence that directly indicates a mixed deposit, supports the idea that changes in taxonomic composition recorded at CC (or lack thereof) have real significance for understanding biochronologic patterns for at least a small portion of the Great Basin and are not an artifact of mixed sediments.

Uranium-Series Age of Flowstone Samples

The two samples of flowstone submitted to UT-Austin for radioisotopic age analysis produced significantly younger ages for the CC fauna than predicted given the previous biochronologic age assignment (see Table 11 for summary data). Two ages were given for each of the UT-Austin samples, on the basis of different estimates for initial thorium levels in the flowstone (15 ppm and 4.4 ppm). Analysis of the first sample (UT-Austin B-1), resulted in ages of 140 ± 15 kya (thousands of years ago; 15 ppm) and 151.2 ± 4.4 kya (4.4 ppm). Analysis of the second sample (UT-Austin B-2) resulted in ages of 136 ± 23 kya (15 ppm) and 153.7 ± 6.4 kya (4.4 ppm).

The third flowstone sample (UMN) came from the matching face of UT-Austin B-1 and was submitted to the University of Minnesota for radioisotopic age analysis in order to provide an independent verification of the results produced by the UT-Austin laboratory. A $^{230}Th/^{234}U$ age was measured that produced a corrected age of 146,020 ± 2584 yr based on an initial thorium value estimate of 4.4 ppm. The congruency of the measured ages from independent laboratories serves as a measure of confidence in the radioisotopic age estimate.

Paleomagnetic Samples

The initial attempt to collect samples for paleomagnetic analysis at CC was unsuccessful. Efforts to use sodium silicate to consolidate unlithified sediments were unsuccessful because of the small grain-size and low permeability of much of the sediment. When sodium silicate was applied to the sediment it simply pooled on the surface, rather than penetrating the sediments. Subsequently, a test was performed using diluted Elmer's glue as a consolidant near the entrance of the cave. The diluted Elmer's glue penetrated slightly more effectively than the sodium silicate (to a depth of 2-3 mm), but as with the sodium silicate much of the solution pooled on the surface.

Initial attempts to collect small samples from the cemented layer were also unsuccessful. Attempts to smooth sediment surfaces so reliable strike and dip measurement could be taken were hampered by variation in sediment size. Larger particles spalled off during attempts to smooth sediment faces with a hand-held rasping saw and consistently caused greater unevenness to the sediment face. As a result, the single, large, block sample was collected. Given time constraints related to the excavation permit and the length of the field season, further attempts to collect multiple paleomagnetic samples had to be abandoned for the current project.

Two IRM analyses on sediment samples from the oriented block support an interpretation that magnetite was the dominant magnetic mineral in sediments from Cathedral Cave (Fig. 36). AFD analyses indicated normal polarities for three of the four cubed samples (Figs. 37-39; Table 12; Appendix 4). One sample indicated a reversed

polarity, but given the data associated with the sample, I interpret this as an error in labeling/orientation of the sample. The record of normal polarity in the CC sediments is consistent with ages based on previous biochronologic estimates (750 to 850 ka) if the sediments date to the younger end of this time range, and the new age estimate based on U-series analyses presented above (~ 150 ka; see Table 11).

Arvicoline Rodents from Cathedral Cave

As expected, the 844 m1s of arvicoline rodents that were identified during the course of this project represent an assemblage nearly identical to that reported from the adjacent 1989 excavation (Table 2). The recovery of two lower first molars of a muskrat (*Ondatra*) represents a new, important taxonomic record for the site. Although a brief overview of the fauna from CC was presented elsewhere (Chapter 1), the relevance of the arvicoline rodent fauna for both chronology and broader biochronologic patterns warrants a brief, independent presentation of the characters used to identify individual taxa. Identification criteria and abundance data are presented for individual taxa below.

Phencomys cf. *P. gryci*

Referred Specimens-See Appendix 5.

Description-Thirty-one of the 844 m1s (3.7%) included in this study were identified as *Phenacomys* cf. *P. gryci*. Lower first molars of *Phenacomys gryci* are rooted, lack cementum in the reentrant angles, and have lingual triangles that are asymmetrically elongated with respect to the labial triangles (Fig. 40; Repenning et al., 1987; Bell and Barnosky, 2000). The m1 of *Phenacomys gryci* usually has five triangles on the m1 with the fifth triangle being broadly confluent with the anterior cap (Repenning et al., 1987;

Bell and Barnosky, 2000). In specimens identified as *Phenacomys* cf. *P. gryci* from CC, 14 specimens had three fully closed triangles on the m1, 13 had four fully closed triangles, and four specimens had five closed triangles. In specimens with fewer than five closed triangles the degree of closure of the T4 and T5 varied from being confluent to exhibiting incipient closure. The presence of this latter morphology differs slightly from published descriptions (e.g., Repenning et al., 1987; Bell and Barnosky, 2000), but the specimens have anterior cap morphologies that most closely resemble *P. gryci*. In other words, they lack any evidence of a well-developed T6, a feature reported in other species of *Phenacomys* (Bell and Barnosky, 2000). Additionally, in three of the four 5-triangle forms there is evidence of a "*Mimomys* kante" on the T4. This feature, a small enamel protuberance situated anterior to T4, is present in most specimens identified as *P. gryci* from the Pit locality (Bell and Barnosky, 2000). Some indication of a *Mimomys* kante was present on the T4 in 24 of 31 specimens identified as *P. gryci*.

Phenacomys gryci was previously reported from Alaska, Froman Ferry (ID), and localities in Porcupine Cave (Repenning et al., 1987, 1995; Bell et al., 2004a). Certain features of specimens of *Phenacomys* cf. *P. gryci* from CC emphasize the need for further analysis of variation in specimens assigned to this taxon. The original diagnosis for the species indicated that a *Mimomys* kante was always present on T4 except in nearly unworn specimens (Repenning et al., 1987). Seven worn CC specimens lack this structure. Additionally, Repenning et al. (1987) indicated the presence of short dentine tracts in *P. gryci*. Higher dentine tracts occur in CC specimens when compared to the type specimens of *P. gryci* (USNM 264295-264299). It seems likeley that these may

represent a distinct taxon, but until an evaluation of all specimens referred to *P. gryci* can be completed, I am satisfied to refer the CC specimens to *Phenacomys* cf. *P. gryci*.

Phenacomys sp. (not *Phenacomys* cf. P. *gryci*)

Referred Specimens-See Appendix 5.

Description-Six specimens (< 1%) were identified as a species of *Phenacomys* other than *Phenacomys* cf. *P*. *gryci*. These m1s have characters found in all *Phenacomys* (e.g., rooted, asymmetrically elongated lingual triangles, lacking cementum in reentrant angles). Unlike the m1 of *P*. *gryci*, they exhibit five fully closed triangles and a well-developed T6 that is confluent with a hooked anterior cap. With the exception of one specimen (TMM 43693-2724) that exhibits a unique structure on the T6, any resemblance of a '*Mimomys* kante' structure found in *P*. *gryci* is lacking in these specimens. One specimen (43693-2725) lacks the anterior portion of the tooth but retains evidence of roots, at least 5 closed, alternating triangles, asymmetrically elongated lingual triangles, and cementless reentrant angles.

Allophaiomys pliocaenicus

Referred Specimens-See Appendix 5.

Description-Sixteen of 844 (1.9%) specimens were identified as *A*. *pliocaenicus*. Lower first molars identified as *A*. *pliocaenicus* are unrooted and have cementum in the reentrant angles. This taxon is characterized by the presence of three closed alternating triangles followed by well-developed primary wings (T4 and T5) that are confluent with the anterior cap (Fig. 41; Repenning, 1992; Bell and Barnosky, 2000). In 14 specimens from CC, the primary wings are broadly confluent with the anterior cap. However, in two instances (43693-1925, -1933), the T4 was only narrowly confluent with the T5/anterior

cap. In all specimens T1 is larger than T2 (i.e., greater labial-lingual width), a feature similar to that seen in specimens of *Microtus*.

Mictomys meltoni or *M. kansasensis*

Referred Specimens-See Appendix 5.

Description-Five specimens (<1%) were identified as *Mictomys meltoni* or *kansasensis*. Initially, these specimens were identified as *Mictomys* sp., but they have characters consistent with those given for *Mictomys meltoni* or *M. kansasensis* from Porcupine Cave, Colorado (Bell et al., 2004a). All five specimens exhibit a shift in the axis of m1 to the far labial side of the tooth (Fig. 42). As a result there are no distinct triangles on the labial side of the tooth (i.e., T2); the lingual triangles are asymmetrically enlarged to such a degree that the m1 in this species is characterized by the presence of only 2 closed, non-alternating triangles (Bell and Barnosky, 2000). Like most other arvicolines with unrooted molars, cementum occurs in the reentrant angles of these species and is evident only in the lingual reentrant angles of CC specimens. Cathedral Cave specimens identified as *Mictomys meltoni* or *M. kansasensis* show variation in the enamel thickness of the anterior walls of T1 and T2. All specimens have thicker enamel on the anterior walls than on the posterior walls, a feature previously used to distinguish *M. meltoni* and *M. kansasensis* from the extant *M. borealis* (Paulson, 1961). Characters that can be reliably used to distinguish *M. kansasensis* from *M. meltoni* are not known at this time (Bell et al., 2004a).

Mictomys sp.

Referred Specimens-See Appendix 5.

Description-A single m1 was identified as *Mictomys* sp. Although the characteristics of the specimen were consistent with *Mictomys meltoni* or *M. kansasensis*, heavy etching on the specimen made it difficult to assess the relative thickness of enamel bands on T1 and T2.

Lemmiscus curtatus

Referred Specimens-See Appendix 5.

Description-The sagebrush vole is one of the most common arvicoline taxa from CC with 344 identified specimens (40.8%). General characteristics of the m1 of *L. curtatus* include unrooted molars, a T1 and T2 of roughly equal labial-lingual width, and the presence of cementum in the reentrant angles. Most modern populations of this taxon have five closed, alternating triangles on the m1 with a well-developed T6 that is confluent with the anterior cap (Barnosky and Bell, 2003). The majority of specimens (n=299) from CC generally conform to this morphology (Fig. 43a). Variants in the 5-triangle morphology occur in seven specimens where the T6 is either pinched from the anterior cap (six specimens) or exhibits incipient closure from the anterior cap (one specimen). One specimen (43693-2027) had five fully closed triangles but was missing the anterior cap. The remaining m1s of *L. curtatus* retain morphologies that vary in the number of fully closed triangles. Three m1s of *L. curtatus* from CC have a morphology where there are six fully closed, alternating triangles.

Thirty-four specimens from CC represent a 4-triangle m1 morphotype of *L. curtatus* where there are only four fully closed triangles (Fig. 43b). In these specimens, the fifth triangle is either confluent with (20 specimens), pinched from (12 specimens), or

exhibits incipient closure from the sixth triangle/anterior cap complex T6 (two specimens). The 4-triangle morphotype is known only from the fossil record (see Bell and Jass, 2004 for discussion).

Microtus meadensis

Referred Specimens-See Appendix 5.

Description-Twenty m1s (2.4%) were identified as *M. meadensis*. The lower first molars of *M. meadensis* are unrooted and are characterized by the presence of three fully closed, alternating triangles. Like other *Microtus*, T1 is larger than T2 in all specimens. In contrast to extant species of *Microtus*, the primary wings (T4 and T5) are confluent with one another rather than closed from each other (Fig. 44). Labial reentrant angle 4 and lingual reentrant angle 5 are well developed and cementum is present in the reentrant angles. Both primary (T4 and T5) and secondary wings (T6 and T7) are present although there is some variation in the development of the secondary wings. For example, in 43693-1674 there is only weak development of the secondary wings.

Across the recovered sample, the primary wings exhibit variable degrees of closure with respect to the secondary wing/anterior cap complex. The primary wings are fully closed from the secondary wings (16 specimens), exhibit pinching from the secondary wings (1 specimen), exhibit incipient closure from the secondary wings (1 specimen), or are narrowly confluent with the secondary wings (2 specimens).

Microtus paroperarius

Referred Specimens-See Appendix 5.

Description-Fifty-six specimens (6.6%) were identified as *M. paroperarius*. As in other *Microtus*, lower first molars are unrooted, T1 is larger than T2, and cementum occurs in

the reentrant angles. Lower first molars of *M. paroperarius* have four closed, alternating triangles. In most specimens (40), the fifth triangle is well developed and is generally confluent with the secondary wings (if present) and anterior cap (Fig. 45a; Bell and Barnosky, 2000). Other morphotypes retained evidence of pinching of T5 from the secondary wings and/or anterior cap (seven specimens; Fig. 45b), or incipient closure of T5 from the secondary wings and/or anterior cap (two specimens).

The remaining six specimens of *M. paroperarius* have uncommon features with respect to the open triangles (T5 and subsequent triangles) and anterior cap, and they warrant individual description. Two specimens (TMM 43693-2354 and –2355) have only three closed triangles and have well-formed primary wings that are confluent with the anterior cap. Initially this supported an identification of *Allophaiomys pliocaenicus*. However, further comparisons of the specimens show greater overall similarity to *M. paroperarius* evidenced primarily by the occurrence of a well-developed fifth lingual reentrant angle. In a single specimen (TMM43693-2346), T4 is only pinched from the T5/anterior cap complex. TMM 43693-2330, -2332, and -2353, have 4 closed triangles as in *M. paroperarius*. T5 and T6 are both well developed and are confluent with one another, but the T5/T6 complex exhibits incipient or complete closure from a T7/anterior cap complex.

Microtus sp.

Referred Specimens-See Appendix 5.

Description-Three hundred sixteen specimens were identified as *Microtus* sp. and account for 37.3% of the entire arvicoline fauna. Specimens identified as *Microtus* sp. are either poorly preserved and retain at least some of the characters discussed below (2

specimens), or represent common morphologies of the m1 (313 specimens) observed in several extant species of North American *Microtus*. Lower m1s identified as *Microtus* sp. from CC are rootless and have at least five closed, alternating triangles. T1 has distinctly larger labial-lingual width than T2. The secondary wings are well-developed and are typically confluent with the anterior cap. Cementum is present in the reentrant angles.

A minimum of 12 extant species of *Microtus* exhibit an m1 morphology consisting of five or six closed triangles (Hall, 1981; Bell et al., 2004a). Previous attempts to identify species-diagnostic characters for isolated teeth of *Microtus* did not include all species (Smartt 1972, 1977; Wallace, 1999). As a result, the utility of these studies is equivocal until additional taxa are analyzed (Bell et al., 2004a).

Lower first molars of *Microtus* sp. from Cathedral Cave exhibit extensive variation in occlusal morphology. The most common morphological pattern consists of five closed triangles and well-developed secondary wings that are confluent with the anterior cap (248 specimens; Fig. 46). Other m1 morphological states include five closed triangles and a T6 that is pinched from the T7/anterior cap (22 specimens), five closed triangles and a T6 that exhibits incipient closure from the T7/anterior cap (12 specimens), five closed triangles and secondary wings that are pinched from the anterior cap (one specimen), five closed triangles with a well-developed T6 but poorly developed T7 (two specimens), five closed triangles but weakly developed secondary wings (one specimen), five closed triangles with a T6 and hooked anterior cap, but no T7 (one specimen), five closed triangles with well-developed secondary wings that are closed from the anterior cap (one specimen), six closed triangles with a confluent T7/anterior cap complex (22

specimens), six closed triangles with a weakly developed T7 (one specimen), seven closed triangles (one specimen), and a specimen that appears similar to the standard 5-triangle form but has a confluent T1 and T2 (one specimen). The morphotype of each specimen is listed individually in Appendix 5.

Ondatra zibethicus

Referred Specimens-See Appendix 5.

Description-Two lower first molars were identified as *O. zibethicus* and account for <1% of the total arvicoline fauna (Fig. 47). Both specimens are rooted, contain five closed, alternating triangles, and have degraded cementum present in the reentrant angles. The secondary wings are confluent with the anterior cap. Specimens of *Ondatra* can be preliminarily distinguished from most other arvicolines on the basis of their large size.

Plots of length versus width of the m1 in muskrats document an overall increase in size from the Pliocene to modern (Nelson and Semken, 1970). Measurements of the m1 in muskrat specimens from CC are summarized in Table 13 and discussed below. Lower first molars of muskrats from CC fall within the size range of *Ondatra zibethicus*. Although size may not be the best criterion to use for species identification, the position of the CC specimens along the chronocline established by Nelson and Semken (1970) has chronological significance and a taxonomic allocation to *O. zibethicus* reflects this (see discussion below).

Arvicolinae indeterminate

Referred Specimens-See Appendix 5.

Description-Fourty-four of the 844 m1s (5.2%) included in this study were identified as indeterminant arvicolines. These specimens were either fragmentary or so poorly preserved that a confident taxonomic placement was not possible.

Other specimens

Description-In a few instances, individual specimens could not be confidently referred to a particular taxon. Unlike specimens identified as 'Arvicolinae indeterminant', these specimens were not necessarily poorly preserved or broken. They retain morphological traits that may represent variations on the taxa listed above, but I was not confident in their taxonomic placement. I mention these specimens individually because future studies may permit reliable placement of these rare (with respect to the CC fauna) morphotypes.

TMM 43693-2729 may represent either *Phenacomys* cf. *P. gryci* or *Mimomys* sp. The m1 is rooted with three closed, alternating triangles. T4 is pinched from T5 and the anterior cap. There is distinct expression of a '*Mimomys* kante' anterior to T4. The position of the '*Mimomys* kante' and poor preservation (that prevented assessment of the presence or absence of cementum) limited my confidence in the identification of this specimen.

TMM 43693-2730 has an occlusal pattern that is similar to *Phenacomys* sp. (not *gryci*) but lacks evidence of roots. The lingual triangles are asymmetrically elongated and there are at least six alternating triangles. In occlusal view the triangles appear confluent whereas ventrally they appear closed; perhaps an indication that the specimen is a juvenile. The reentrant angles lack cementum.

TMM 43693-2731 is identical to the 4-triangle form of *Lemmiscus curtatus* with one exception. T1 is greater than T2 in labial-lingual width, a feature used to identify *Microtus* (see above).

TMM 43693-2732 may represent a variant of *Microtus meadensis*. The specimen is unrooted, has cementum in the reentrant angles, and has a T1 that is larger than T2. Three closed, alternating triangles precede primary wings that are confluent with each other as well as the T6/anterior cap complex. A fifth lingual reentrant is present but there is no evidence of a fourth labial reentrant as in *M. meadensis*.

DISCUSSION

The Age of the Cathedral Cave Fauna

Previous estimates for the age estimates for mammalian fossils excavated from Room 2 at Cathedral Cave were late Pleistocene (~15,000 to 24,000 yr B.P; Bell, 1990; Mead et al.,1992) or middle Pleistocene (750 ka to 850 ka; Bell, 1995; Bell and Barnosky, 2000). Because of the taxonomic composition of the arvicoline fauna and potential inaccuracies in previous radioisotopic age estimates, this project began with the working hypothesis that the CC fauna was likely middle Pleistocene (750 ka to 850 ka) in age.

Initial data on arvicoline rodents collected during the 2003 excavation were consistent with an age of 750 ka to 850 ka. The arvicolines collected during the 2003 excavation are taxonomically equivalent to those reported from the 1989 excavation (Bell, 1995; Bell and Barnosky, 2000). *Lemmiscus curtatus* and *Microtus* sp. are the

most common taxa, with others occurring in lower relative abundance (see Chapter 7). There is no pattern of faunal replacement evident in the arvicoline rodent fauna. No taxa with an $n \geq 5$ are restricted to specific levels of the excavated sequence, and the fauna appears to be fairly taxonomically homogenous throughout.

The recovery of lower m1s of muskrat at CC means that the fauna is identical (at the generic level) to that from the Pit locality of Porcupine Cave, CO (when the 1989 and 2003 CC excavations are considered together; see Table 2). While this is consistent with previous biochronologic age estimates, additional examination of the muskrat teeth from CC provided evidence of an age younger than or equal to 670 ka.

Patterns of morphological evolution in the lower first molar of muskrats were previously evaluated and changes in the size of this tooth represent one of the most well-documented cases of evolutionary change during the Quaternary (Fig. 48; Nelson and Semken, 1970**;** Martin, 1996). When plotting length versus width of the m1 in muskrats, there is an increase in size from older to younger deposits (Nelson and Semken, 1970). Length and width measurements for m1s of muskrat from CC were as follows: TMM 43693-2692—L = 7.19 mm, W = 3.05 mm; and TMM 43693-2691—L = 6.73+ mm, 2.71 mm. TMM 43693-2691 was slightly broken and the length measurement represents a minimum based on the preserved, measurable portion of the tooth.

When plotted on the chronocline established by Nelson and Semken (1970), muskrat specimens from Cathedral Cave are larger than would be predicted given an age estimate of 750 ka to 850 ka (Fig. 48). Their size plots with specimens that are younger than muskrat fossils from the Cudahy Fauna of Kansas, a fauna whose age has an upper boundary of 0.67 ma based on radioisotopic ages on the Lava Creek B Ash (Fig. 48; Izett

et al., 1992; Izett and Honey, 1995; Bell et al., 2004b). Given an age estimate of 750 ka to 850 ka, muskrat specimens from CC should have plotted on the opposite side of the Cudahy specimens (Fig. 48). More recent data on chronologic variation in the lower m1 of muskrats is also consistent with a younger age assignment (Martin, 1996).

This discovery has at least two potential explanations. First, muskrats from CC may not follow the clinal variation observed by Nelson and Semken (1970) and Martin (1996). Conversely, the muskrat specimens may be consistent with that pattern of clinal variation and indicate a younger age for the CC fauna. The results of radioisotopic dating and paleomagnetic data for CC (presented above) are consistent with the latter assertion. Because of the congruence of U-series ages from independent laboratories, and the position of the flowstone samples from the base of the excavation, I accept a range from 146.02±2.584 ka to 151.2±4.4 ka as the maximum possible age range for fossils collected during the 2003 excavation.

Biochronologic Significance

Arvicoline rodent fossils are important biochronologic indicators for the Pleistocene, particularly in deposits that lack large taxa such as *Mammuthus* or *Bison*. If not for the assemblage of arvicoline rodents preserved at Cathedral Cave, it is probable that the initial late Pleistocene age estimates for the site would have been accepted. Despite the fact that the age determination accepted here differs from both previous age estimates (uranium-series and biochronologic), the primary reason that this analysis was undertaken was because of the presence of an intriguing arvicoline rodent assemblage.

Our understanding of long-term faunal patterns throughout the Pleistocene is enhanced by the new age data for the arvicoline rodent fauna from Cathedral Cave.

Accepting the oldest possible uranium series age from CC as 146.02±2.584 ka to 151.2±4.4 ka, there are at least 3 chronologic range extensions recorded at Cathedral Cave. Chronologic extensions of *Allophaiomys pliocaenicus* (from ~840 ka), *Microtus meadensis* (from 252 ± 30 ka), and *Microtus paroperarius* (from 252 ± 30 ka) to at least as young as 146.02±2.584 ka to 151.2±4.4 ka are warranted by the data presented here. The record of *Phenacomys* cf. *P. gryci* may also represent a range extension if taxonomic issues can be satisfactorily addressed. Therefore, the utility of these taxa for the age refinement of deposits lacking external age control is diminished because they are now known to have persisted over a longer time span.

Given the large amount of data collected on Quaternary deposits in North America, the persistence of several extinct arvicoline rodent taxa into the late Pleistocene was a surprising discovery. The absence of *Phenacomys gryci* and *Allophaiomys pliocaenicus* from deposits that definitively post-date the Pit locality sequence (750-850 ka) was disconcerting because of the scale of the chronologic range extension represented by data from CC. Only a single record of *Allophaiomys* is known that may post-date the Pit locality (Wellsch Valley, Alberta; Stalker and Churcher, 1982). However, when viewed in the context of available data concerning faunal patterns in North America between 670,000 and 50,000 years ago the range extensions are less surprising.

There are few localities with external age control known from that time span, and in western North America there are only two (American Falls and the Medicine Hat Sequence) that span much or all of the Irvingtonian-Rancholabrean boundary (210 ka -

160 ka; *sensu* Bell et al., 2004b). Therefore, data from Cathedral Cave are distinct because they begin to fill a significant knowledge gap in our understanding of the Pleistocene faunal record of North America. The chronologic range extensions of *A. pliocaenicus*, *Microtus meadensis*, *M. paroperarius*, and possibly *Phenacomys gryci*, that are recorded at Cathedral Cave are only 'surprising' in the sense that they were unknown; there is no incongruence with other data sets because so few comparable data sets are available. What remains questionable is the degree to which the chronologic data recorded at Cathedral Cave are broadly applicable to other regions of North America.

Comparisons of the chronologic history of arvicoline rodents preserved at CC, comparison of the CC arvicoline rodent fauna to taxonomically similar faunas from other portions of the western United States, and a brief discussion of documented aspects of the faunal history of the Great Basin are necessary for interpreting the signficance of the CC arvicoline fauna. Previous estimates of the chronologic distribution of arvicoline taxa from CC are summarized in Figure 49. The chronologic range extensions of *Allophaiomys pliocaenicus*, *Microtus meadensis*, *Microtus paroperarius*, and possibly *Phenacomys gryci* merit comparisons with other western faunas (~ Rocky Mountains and westward) containing these taxa in order to evaluate the implications of the CC fauna for Pleistocene biochronology.

Regional Context—In addition to Cathedral Cave, arvicoline rodent faunas from the western United States that contain *Allophaiomys pliocaenicus* (or *Allophaiomys* sp.), *Microtus meadensis*, *M. paroperarius*, *Phenacomys gryci*, or a combination thereof are summarized in Table 14. *Allophaiomys pliocaenicus*, *Microtus paroperarius*, and *Phenacomys gryci* are not known from any of the California localities listed in Table 14.

Microtus meadensis is reported from three sites in California, all of which have uncertainty associated with their age. A record of *Microtus meadensis* comes from the Ocotillo Conglomerate in the Anza-Borrego Desert (White et al., 2005). The age of the base of the Ocotillo Conglomerate ranges from 1.0 to 1.2 mya (see Dorsey, 2005; Remeika, 2005 for discussions), but there are some uncertainties relating to the exact provenience of the specimen that are currently being resolved by other researchers (Lyn Murray, personal communication). Records from the North Livermore Avenue locality and Olive Dell Ranch lack external age that is independent of the faunas themselves (see discussion by Repenning, 1983).

Vertebrate fossils collected from Hansen Bluff, Colorado come from a series of localities within the Alamosa Formation (Rogers et al., 1985). *Microtus meadensis* and *M. paroperarius* were both reported from Hansen Bluff in addition to several other arvicoline rodent taxa (*Mictomys meltoni*, *Microtus* sp., and *Ondatra annectens*; Rogers et al., 1985). Age estimates based on the presence of the Bishop Ash, climatic correlations, and sedimentation rates placed the fauna between 690 kya and 910 kya (Rogers et al., 1985).

All four taxa are known from multiple deposits within Porcupine Cave, Colorado (Bell et al., 2004a). Correlation of these deposits was based on a variety of data (e.g., biochronologic, paleomagnetic, relative abundance; Barnosky and Bell, 2004). Three Porcupine Cave localities (the Pit locality, DMNH Velvet Room, and CM Velvet Room) have paleomagnetic data associated with them that independently support biochronologic age assignments (Friedman and Raynolds, 2004; Barnosky and Bell, 2004). The longest sequence (the Pit) was bracketed between 900 ka to 1.0 mya at the base to 780 ka at the

top and may correlate to portions of the DMNH Velvet Room and the CM Velvet Room (Barnosky and Bell, 2004). Other arvicoline-bearing localities reported from Porcupine Cave that may fall within this age range include the Badger Room, Ferret Room, Fissure Fill A, and Generator Dome (Barnosky et al., 2004; Bell et al., 2004b; Shabel et al., 2004). Only Mark's Sink may be significantly older (Bell et al., 2004b).

The Froman Ferry faunal succession was collected from the Glenns Ferry Formation in southwestern Idaho. Recovered arvicolines include *Mictomys vetus*, *Ophiomys* (*Mimomys*) *parvus*, *Phenacomys gryci*, and *Ondatra idahoensis* (Repenning et al., 1995). The age of this faunal succession is bracketed by a dated basalt (1.58 ± 0.085) that overlies the mammal-bearing strata and the occurrence of magnetically reversed sediments through the entire fossil succession that places the fauna at or above the end of the Olduvai normal polarity subchron (1.77 mya; Bell et al., 2004b). The record of *Phenacomys gryci* represents the earliest known occurrence of that taxon in the conterminous United States (Repenning et al., 1995).

Allophaiomys is known from a series of four undisturbed localities within SAM Cave, New Mexico (Rogers et al., 2000). The age of those localities was bracketed between 850 ka and 1.3 ma based on the presence of *Allophaiomys* and *Mictomys kansasensis*.

A record of a single m1 of possible *Microtus paroperarius* is known from a Los Angeles County Museum locality (LACM 105914) in Oregon (Bell et al., 2004a). There is no associated external age control (Bell et al., 2004a).

Records of *Microtus meadensis* and *Microtus paroperarius* from Salamander Cave (Black Hills, South Dakota) are included here even though they come from a

geographic region located east of the Rocky Mountains. The Black Hills retain biotic affinities with several regions of North America (including the Rocky Mountains), and the region represents a topographically high area relative to the surrounding plains (Turner, 1974). As such, they are potentially analogous to regions of the Great Basin that record altitudinal variations in patterns of dispersal and extinction. In fact, the records of *Microtus meadensis* and *Microtus paroperarius* from the Horse Room of Salamander Cave were the youngest known records of those taxa prior to this report. An age of 252,000 ± 30,000 yr B.P. for the bone-bearing unit from the Horse Room was based on $^{230}Th/^{231}Pa$ ratios obtained from a horse (*Equus*) phalanx (Mead et al., 1996). More conservative uranium-series ages for the fauna from the Horse Room placed it at 451,000 yr B. P. (Mead et al., 1996). In either scenario, the records for *M. meadensis* and *M. paroperarius* from the Horse Room represent young records relative to most of the other data discussed here, as well as data on the multitude of arvicoline faunas known elsewhere from east of the Rocky Mountains (e.g., Cudahy Ash Pit [Hibbard, 1944; Paulson, 1961, Bell and Repenning, 1999], other Meade Basin localities (summarized in Martin et al., 2000, 2003)].

Two faunal assemblages (Locality 1 and Locality 2) from Little Dell Dam, UT contained arvicoline rodents (Gillette et al., 1999). The arvicoline rodent fauna from Locality 1 included a single specimen of *Microtus paroperarius* (Gillette et al., 1999). *Allophaiomys pliocaenicus* and possibly *Phenacomys gryci* were reported from Locality 2 (Gillette et al., 1999). Age estimates for the localities are based on the assemblages of arvicoline rodents. Locality 1 was bracketed between 250 ka and 850 ka whereas Locality 2 was bracketed between 750 ka and 1.3 ma (Gillette et al., 1999).

The Kennewick Road Cut Locality, Washington, contained specimens of *Microtus meadensis* (Rensberger and Barnosky, 1993). The age of the fauna is not well-constrained although upper portions of the stratigraphic section were assigned to the Holocene based on an association with the Mazama Ash (~7,000 yr B. P.; Rensberger and Barnosky, 1993). Lower portions of the section (those containing *M. meadensis*) are now bracketed between 40 and 328 ka on the basis of calcrete chronology (Rensberger and Barnosky, 1993; Bell et al., 2004b).

When contrasted with other western localities containing the taxa of interest here (*Phenacomys gryci*, *Allophaiomys pliocaenicus*, *Microtus meadensis*, and *M. paroperarius*), only Mark's Sink and the Pit locality (both in Porcupine Cave, CO) contain all four taxa (Table 14). Mark's Sink was considered to be a mixed deposit and lacked any form of external age control (Barnosky et al., 2004; Bell et al., 2004a). The arvicoline fauna of Cathedral Cave is most similar to that recovered from the Pit locality (see Tables 2 and 5). As mentioned, the most recent age estimates place the excavated sequence from the Pit locality at 780 ka for the top of the sequence and 1.0 ma for lower units (Barnosky and Bell, 2004).

Accepting that a likely maximum $^{230}Th/^{234}U$ age for the Cathedral Cave is between 146.02±2.584 ka and 151.2±4.4 ka, there is potentially a minimum of 629,000 years that separate taxonomically identical arvicoline rodent faunas from CC and the Pit locality. Individually, the later records of *Microtus meadensis* and *Microtus paroperarius* from Cathedral Cave do not seem quite so extraordinary given that they are known to occur in deposits younger than the Pit locality (i.e., Salamander Cave and the Kennewick Road Cut). The range extensions for *Allophaiomys pliocaenicus* and possibly

Phenacomys gryci indicated by the $^{230}Th/^{234}U$ age for the Cathedral Cave are more significant given that the Pit locality previously represented the youngest independently dated records for both of these taxa.

This chronologic incongruence between nearly identical arvicoline rodent faunas raises two important issues. An alternative age, equivalent to CC, could be hypothesized for portions of the Pit locality. Reversed polarities were recorded in lower portions (levels 8 and 14) of the excavated sequence from the Pit locality and are consistent with current age estimates for the locality (Bell and Barnosky, 2000). However, the level (4) with the most species-rich arvicoline assemblages, and the most similar to CC, occured above levels containing magnetically reversed sediments (Bell and Barnosky, 2000). Hypothesizing a younger age for sediments above level 8 in the Pit locality seems to be a reasonable alternative given the data presented here for CC.

The incongruence of the Pit locality age assignment and CC age assignment also highlights questions about the applicability of biochronologic patterns over large geographic swaths. Specifically, it illustrates the potential for provinciality and diachroneity in biochronologic patterns where geographic regions differ with respect to the timing of immigration, dispersal, and extinction of individual taxa. At a deeper level, it re-emphasizes the possible influence of elevation on biochronologic patterns (Bell and Barnosky, 2000). More comparative data may show that an independent biochronologic consideration of high elevation localities is necessary (Bell et al., 2004a).

Provincialism and Biogeographic Patterns in the Great Basin—Recognition of provinciality and diachroneity is not new or specific to arvicoline rodents (e.g., Repenning, 1987, 1992; Fejfar and Repenning, 1992; Bell, 2000; Bell and Barnosky,

2000). However, when considered in the context of known biogeographic patterns in the Great Basin, the chronologic and paleontologic data from Cathedral Cave provide support for the idea that provincialism may be identified in the fossil record at a smaller geographic scale than previously recognized.

Previous research concerning provincialism and arvicoline biochronology established several North American faunal regions with unique biochronologic patterns (Fig. 50; Fejfar and Repenning, 1992; Bell, 2000). These boundaries are subject to change as additional faunas are recovered and independent dates provide further refinement. Although Repenning (1998) explicitly recognized that these regions were likely to be sub-divided on the basis of latitudinal or altitudinal characteristics, relatively few data have supported his prediction.

The combination of the $^{230}Th/^{234}U$ ages, paleomagnetic data, the arvicoline rodent faunas from Cathedral Cave, and the arvicoline fauna from Smith Creek Cave (see Chapter 4) suggest that the chronological pattern of faunal change in parts of the Great Basin differed significantly from other areas of the western United States. There is little contextual evidence to dispute the age of the Cathedral Cave fauna because minimal data concerning arvicoline faunas that pre-date radiocarbon are available for the Great Basin and western North America in general. Recognition of a distinct biochronology for the area near Cathedral Cave would be premature. However, the taxonomic similarity and age dissimilarity of the arvicoline faunas from Cathedral Cave and the Pit in Porcupine Cave, considered in the context of known biogeographic patterns in the Great Basin, provide enough information to hypothesize that an independent biochronology would be a better reflection of biological reality.

One of the unique faunal characteristics of the Great Basin is the presence of numerous disjunct populations of boreal mammals on isolated mountain ranges (e.g., Brown, 1971, 1978; Grayson, 1993, 2000a). Pleistocene-Holocene climatic shifts probably had a significant role in the development of this pattern. During the cooler, more mesic, late Pleistocene, habitats that would support montane taxa occurred at lower elevations than seen today (Brown, 1978; Grayson, 1993, 2000a). Warm, dry conditions during the Holocene resulted in disappearance of suitable lowland habitats and boreal taxa retreated up-slope where they became isolated on montane islands (Brown, 1978; Grayson, 1993, 2000a). Although new data have forced modifications to our understanding of Brown's original biogeographic model, there is ample evidence that many of the taxa that occur today as disjunct populations were more widespread in the late Pleistocene (see summary provided by Grayson, 1993). Over a short, relatively well-constrained geologic interval (i.e., late Pleistocene-modern), there are known differences in the timing of extirpation of taxa across portions of the Great Basin. In this context it seems likely that the Great Basin would exhibit biochronologic patterns dissimilar to those occurring elsewhere in North America. The disparate ages of the Cathedral Cave and Pit locality arvicoline faunas indicate such dissimilarity.

Another aspect that may be considered in light of the chronologic data from Cathedral Cave is the possible role of topographic variation as an influencing factor on biochronologic provinciality. Currently, the two localities containing the latest known records of *Microtus paroperarius* and *M. meadensis* are from Salamander Cave in the Black Hills of South Dakota, and Cathedral Cave. Both represent depositional settings that would include taxa sampled from topographically high regions that may have acted

as refugia for taxa that could not thrive on the surrounding valleys/plains. Given the recognition of differential timing of extirpation events in isolated mountainous settings in the Great Basin, there is a potential that individual mountain ranges both within and outside of the region will preserve unique biochronologies.

At present, there are limited data (n = 1; Cathedral Cave) to evaluate differential timings of pre-radiocarbon dispersal, extirpation, and extinction events between isolated mountain ranges that occur in the Great Basin. Other localities of similar age in different portions of the Great Basin need to be identified in order to develop a better understanding of the regional biochronology for the entire Pleistocene. There are few sites of comparable age to Cathedral Cave, and those occur outside of the Great Basin. In fact, nearly all of our understanding of arvicoline biochronology is rooted in areas outside of the Great Basin (e.g., the Great Plains). To truly begin to understand the possibility that mountains in the Great Basin preserve unique biochronologies, it will be necessary to develop a regional framework that encompasses data from more sites constrained by external age control. Ideally, both low and high elevation sites of comparable age to Cathedral Cave need to be found so that the influence of elevation can be better evaluated. Unlike Porcupine Cave and Salamander Cave, sites that might be reliably compared within the chronologic framework for the Great Plains, Cathedral Cave truly lacks a biochronologic framework at any elevation. Low elevation arvicoline faunas of comparable age to CC from the Great Basin might not differ from that identified at Cathedral Cave, but such localities are currently unknown for the Great Basin.

CONCLUSIONS

Cathedral Cave contains a diverse arvicoline rodent assemblage similar to that found in the Pit Locality at Porcupine Cave, Colorado. Although recently thought to be similar in age, the two localities now appear to be chronologically separated by approximately 629 ka. New $^{230}Th/^{234}U$ ages derived from *in situ* flowstones indicate a likely maximum age from 146.02±2.584 ka to 151.2±4.4 ka for fossils excavated from Cathedral Cave in 2003. As a result, Cathedral Cave preserves the latest known records of *Allophaiomys pliocaenicus*, *Microtus meadensis*, *Microtus paroperarius*, and possibly *Phenacomys gryci*. The age and composition of the Cathedral Cave fauna in the context of biogeographic patterns in the Great Basin suggests the possibility that mountain ranges in the Great Basin preserve unique biochronologies.

Table 10. Taxa used to define and characterize the Blancan, Irvingtonian, and Rancholabrean LMAs (from Bell et al., 2004b). Arvicoline rodent taxa are in bold. Restricted taxa are known only from the LMA under which they are listed.

Land Mammal Age	Defining Taxa (first appearance)	Restricted Taxa	Characteristic Taxa (first appearance)
Rancholabrean (210-160 ka to 9.5 ka)	*Bison*	*Megalonyx jeffersonii*	*Aplodontia rufa*
		Platygonus compressus	*Vulpes velox*
		Canis dirus	*Felis concolor*
		Panthera atrox	*Alces*
		Miracinonyx trumani	*Ovis canadensis*
			Rangifer tarandus
			Homo sapiens
Irvingtonian (1.35 ma to 210-160 ka)	*Mammuthus*	***Microtus llanensis***	***Ondatra zibethicus***
		Microtus meadensis	***Lemmiscus curtatus***
		Microtus paroperarius	
		Canis armbrusteri	
		Tetrameryx irvingtonensis	
Blancan (4.6-5.2 ma to 1.35 ma)	***Mimomys***		***Microtus*** (5T)
	Ogmodontomys		***Ondatra annectens***
	Ophiomys		***Phenacomys***
			Allophaiomys pliocaenicus

Table 11. Results of radioisotopic age analyses of flowstone samples from Cathedral Cave, NV. UT = sample submitted to The University of Texas at Austin. UMN = sample submitted to the University of Minnesota. The two ages given for the UT samples are based on different estimates of initial ratios of $^{230}Th/^{232}Th$ (15 ppm vs. 4.4 ppm).

Sample	ppb ^{238}U	$\delta\ ^{234}U$	232 ng/g	230 pg/g	Age (ky); 15 ppm	Age (ky); 4.4 ppm
UT B-1	228.6±.2	477±2	55.4±.4	4.46±.02	140±15	151.2±4.4
UT B-2	248.2±.5	452±2	87.7±.6	4.80±.02	136±23	153.7±6.4
UMN	263.9±.5	459.4±2.8	-	-	-	146.02±2.584

Table 12. Summary Fisher statistics for paleomagnetic analyses for four sediment samples from the cemented level at Cathedral Cave. Sample numbers correspond with graphic representations of data presented in figures 37-39.

Sample	Declination	Inclination	a95	R	k	n
1	12.552473	54.598082	13.347323	11.046777	11.539799	12
2	203.825858	46.084613	4.055610	18.740837	69.454283	19
3	351.044802	54.716558	16.413758	11.366442	7.345927	13
4	357.912946	51.390113	5.320713	16.651556	45.918459	17

Table 13. Measurements of muskrat specimens from Cathedral Cave (in mm). Length and width measurements were taken to the nearest 0.01 mm at the girth of the tooth using Mitutoyo digital calipers. Tract height was measured on the buccal side of the anterior cap complex from the base of the fourth buccal reentrant angle on the m1. Tract height was measured using an ocular micrometer.

Specimen	Length	Width	Dentine Tract Height
610	7.19	3.05	4.1
611	6.73+	2.71	2.6

Table 14. The geographic and chronologic distribution of *Phenacomys gryci* (*Pg*), *Allophaiomys pliocaenicus* (*Ap*), *Microtus meadensis* (*Mm*), and *Microtus paroperarius* (*Mp*) in the western United States. An asterisk (*) after the age denotes that there is no accurate age control assessment that is independent of the fauna itself. (PC) = Porcupine Cave. ? = uncertain record. Footnotes provide individual citations.

Site	Age	*Pg*	*Ap*	*Mm*	*Mp*
Anza-Borrego Desert, CA[1]	Unknown	-	-	X	-
North Livermore Ave. locality, CA[2]	450 ka*	-	-	X	-
Olive Dell Ranch, CA[3]	Unknown*	-	-	X	-
Hansen Bluff, CO[4]	690-900 ka	-	-	X	X
Badger Room (PC), CO[5]	850-950 ka*	X	X	-	-
Crystal Room (PC), CO[5]	Unknown*	-	-	-	X
Ferret Room (PC), CO[5]	Unknown*	X	-	-	-
Fissure Fill A (PC), CO[5]	>800 ka*	X	X	-	X
Generator Dome (PC), CO[5]	Mixed*	-	X	-	-
Gypsum Room (PC), CO[5]	Unknown*	X	X	X	-
Mark's Sink (PC), CO[5]	Mixed*	X	X	X	X
New Passage (PC), CO[5]	Unknown*	-	-	X	-
Pit locality (PC), CO[5]	600-800 ka to 1.0 ma	X	X	X	X
CM Velvet Room (PC), CO[5]	<780 ka	-	X	X	X
DMNH Velvet Room (PC), CO[5]	>600 ka to >800 ka-<1.0 ma	-	X	X	X
Will's Hole (PC), CO[5]	Unknown*	-	-	X	-
Froman Ferry, ID[6]	>1.5-<1.67 ma	X	-	-	-
Cathedral Cave, NV	146.02±2.584 ka-151.2±4.4 ka	?	X	X	X
SAM Cave, NM[7]	850 ka-1.3 ma*	-	X	-	-
LACM 105914, OR[8]	Unknown*	-	-	-	X
Salamander Cave, SD[9]	252±30 ka	-	-	X	X
Little Dell Dam Locality 1, UT[10]	250-850 ka*	-	-	-	X
Little Dell Dam Locality 2, UT[10]	750 ka –1.3 ma*	?	X	-	-
Kennewick Road Cut, WA[11, 12]	40-328 ka	-	-	X	-

[1]Repenning, 1992; [2]Repenning, 1983; [3]Repenning, 1983; [4]Rogers et al., 1985; [5]Bell et al., 2004a; [6]Repenning et al., 1995; [7]Rogers et al., 2000; [8]Bell et al., 2004a; [9]Mead et al. 1996; [10]Gillette et al., 1999; [11]Rensberger et al., 1984; [12]Rensberger and Barnosky, 1993

Figure 33. Subsampled areas of flowstone sample 3, collected *in situ* from CC. B-1 and B-2 represent unique lab identification numbers and correspond to data in Table 12. The subsample analyzed by the University of Minnesota (not pictured) was taken from a matching face of B-1. Arrows indicate subsampled regions. Scale bar = 1 cm.

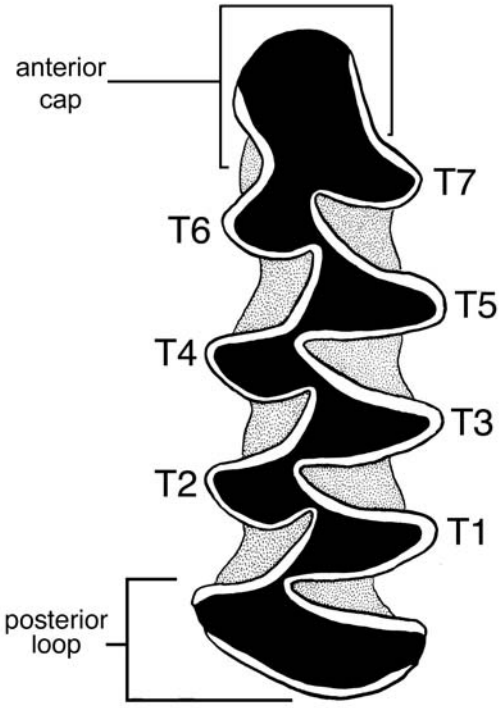


Figure 34. General structure and features of the lower first molar in arvicoline rodents. Modified from Bell and Jass (2004). T is an abbreviation for 'Triangle' (e.g. T1 = Triangle 1).

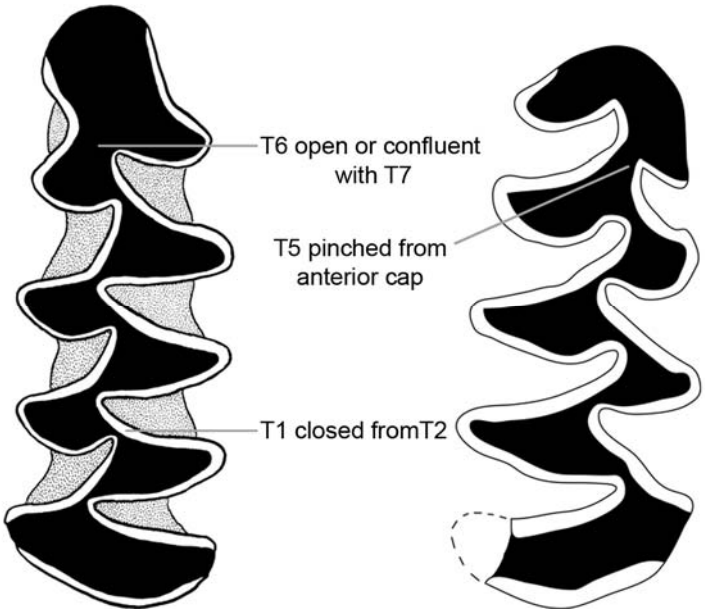


Figure 35. General variation in the closure of individual triangles in the m1 of arvicoline rodents.

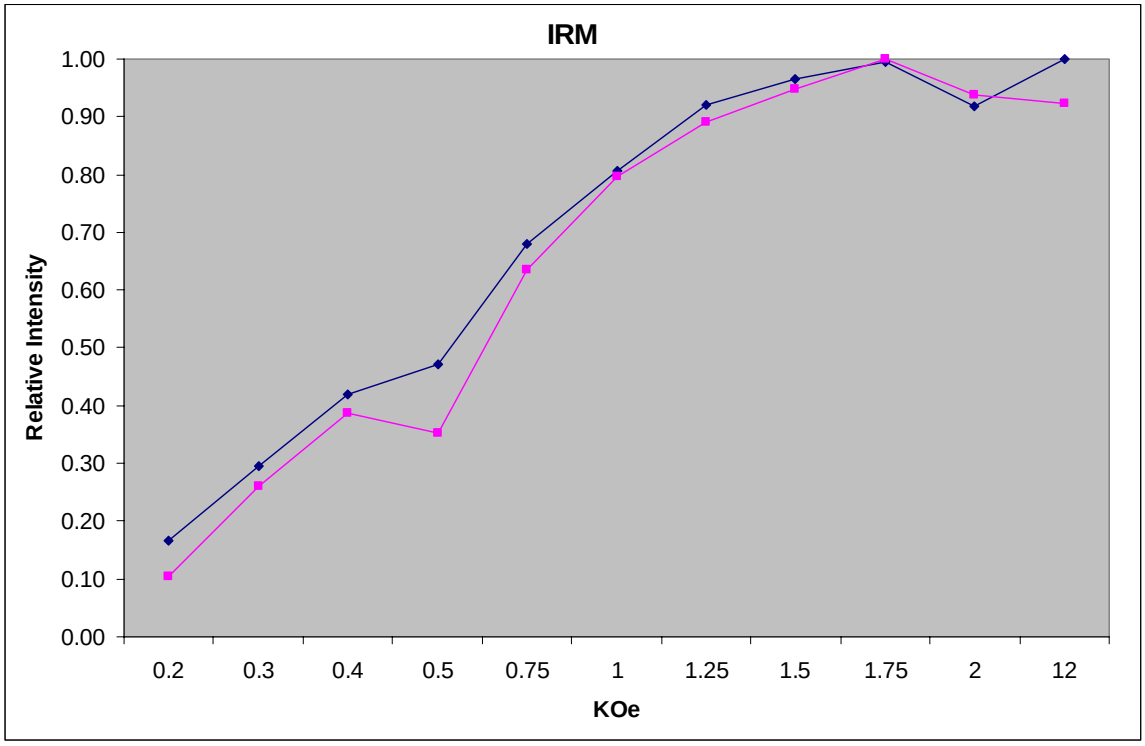


Figure 36. Results of IRM analysis of two sediment samples from the bulk block collected for paleomagnetic analyses. The curve appears somewhat flattened because saturation was attained early (at 1.75 KOe), and steps between 2 KOe and 12 KOe were not measured. Note change in x scale.

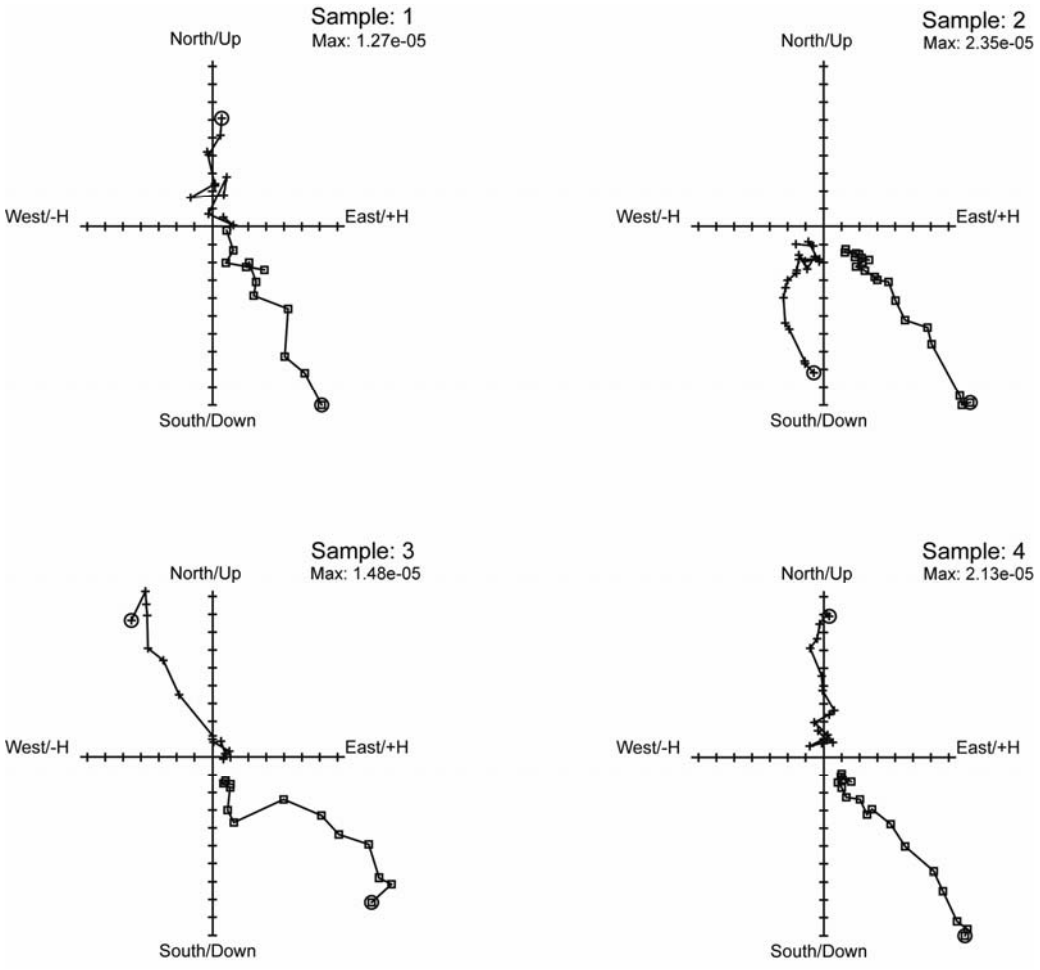


Figure 37. Vector end-point diagrams for paleomagnetic analyses of sediments from the cemented level at Cathedral Cave, NV. "+" = declination, "□,■" = positive & negative inclination.

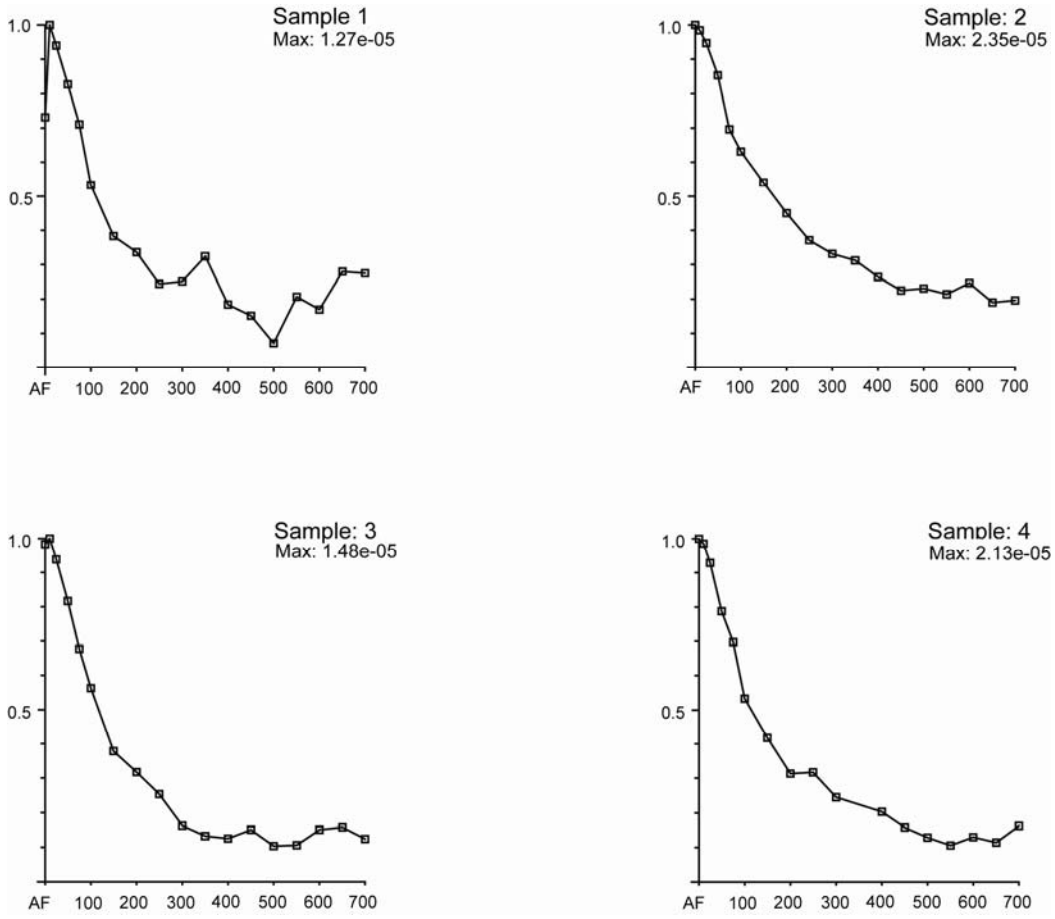


Figure 38. Intensity plots of paleomagnetic samples from Cathedral Cave, NV, with intensity standardized to highest value. Samples were measured to AF 1000 but only plotted here to AF700.

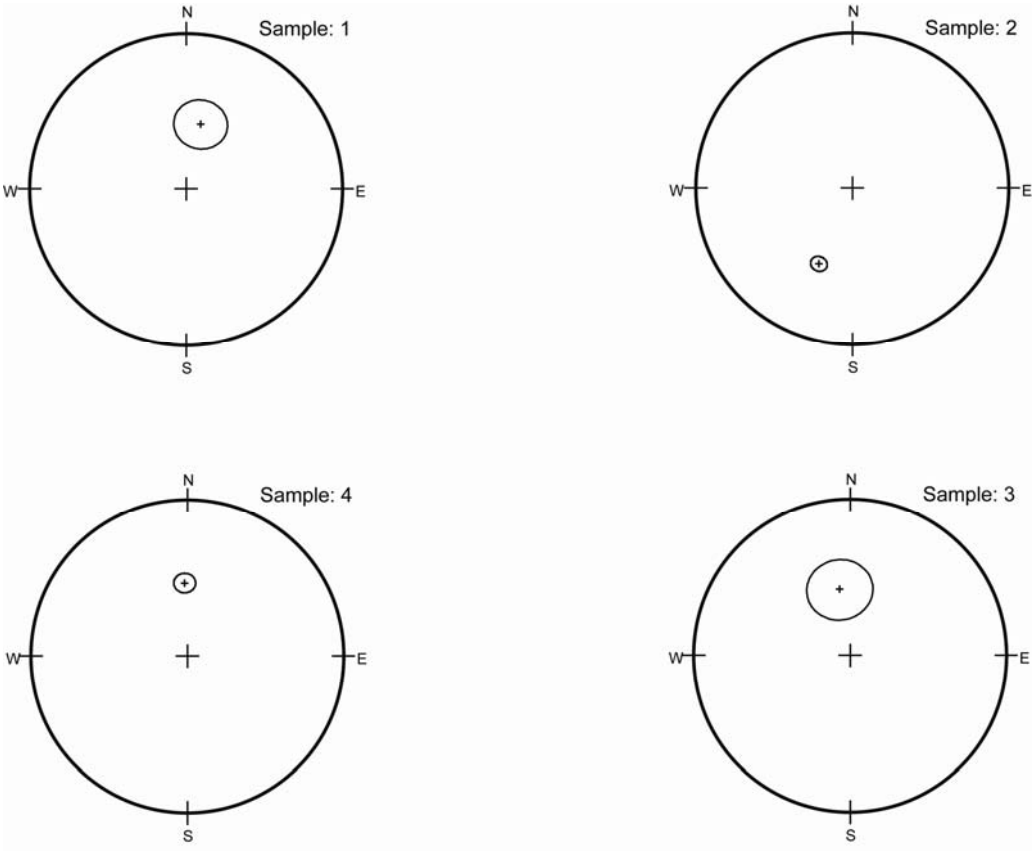


Figure 39. Stereoplots of paleomagnetic data from Cathedral Cave, NV. Fisher statistics are presented in Table 12. "+" = mean; circle indicates alpha 95 value.

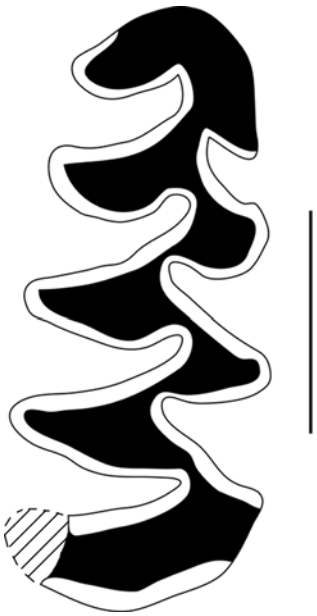


Figure 40. Lower right m1 of *Phenacomys gryci* (43693-2694) from Cathedral Cave. Scale bar = 1 mm.

Figure 41. Lower left m1 of *Allophaiomys pliocaenicus* (43693-1931) from Cathedral Cave. Scale bar = 1 mm.

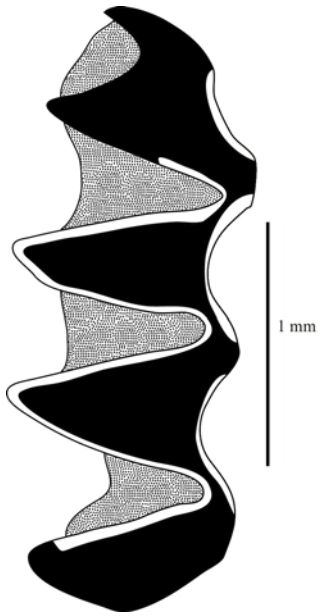


Figure 42. Lower right m1 of *Mictomys meltoni* or *M. kansasensis* (43693-1933) from Cathedral Cave. Scale bar = 1 mm.

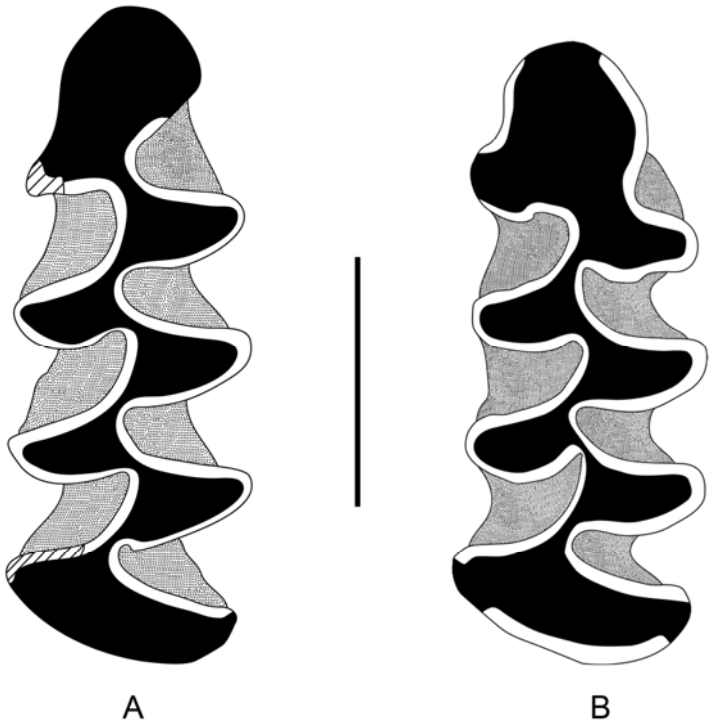


Figure 43. Common morphologies of the m1 in *Lemmiscus curtatus* from Cathedral Cave. A. Left m1 (43693-2046) with five closed triangles. B. Left m1 (43693-2163) with four closed triangles. Scale bar = 1 mm.

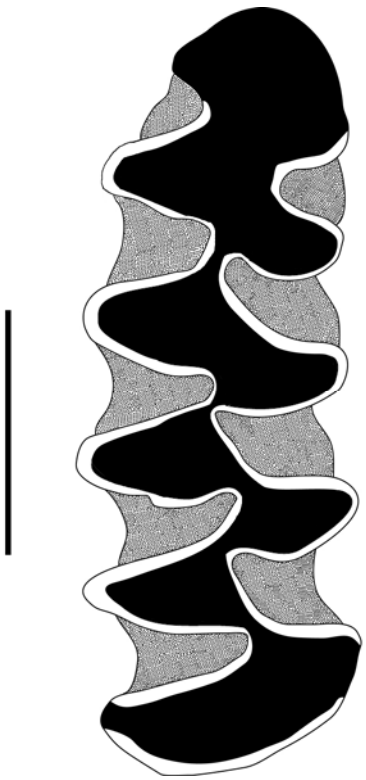


Figure 44. Lower right m1 of *Microtus meadensis* (43693-2314) from Cathedral Cave. Scale bar = 1 mm.

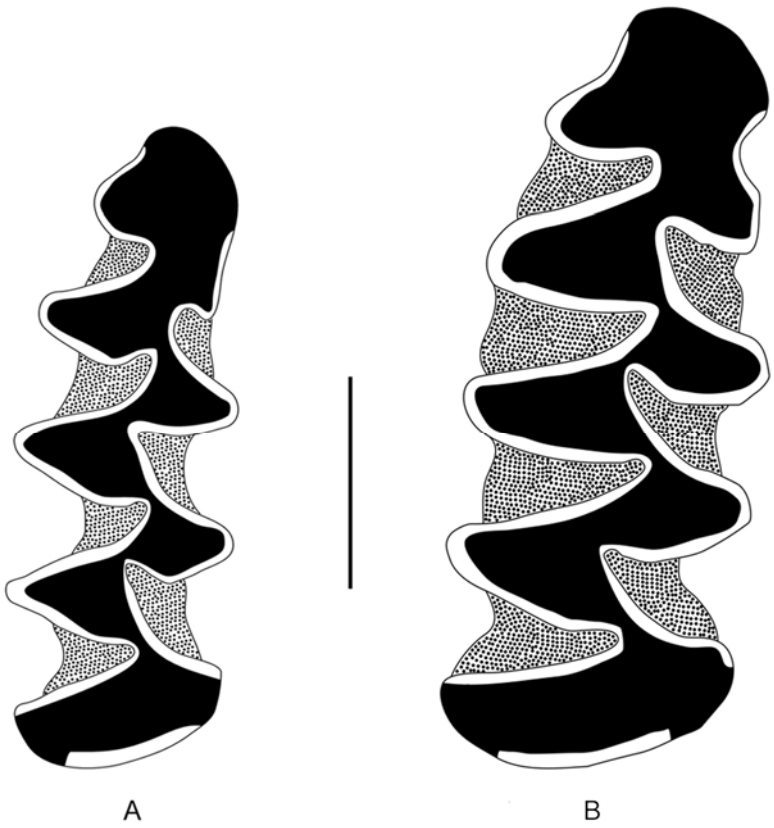


Figure 45. Common m1 morphotypes of *Microtus paroperarius* from Cathedral Cave, Nevada. A. Right m1 (43693-2346) with a well-developed T5 that is confluent with the anterior cap. B. Right m1 (43693-2364) with a T5 that is pinched from the anterior cap. Scale bar = 1 mm.

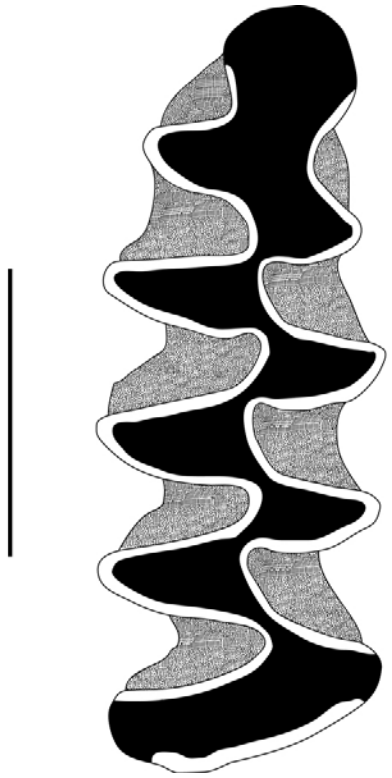


Figure 46. Right m1 of the common form of 5-triangle *Microtus* sp. (43693-2621) from Cathedral Cave, Nevada. Scale bar = 1 mm.

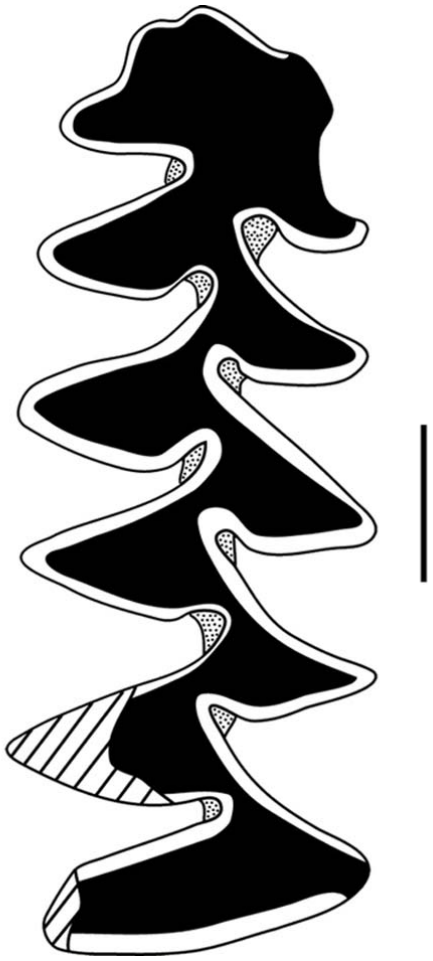


Figure 47. Right m1 of *Ondatra zibethicus* (TMM 43693-2692) from Cathedral Cave, Nevada. Scale bar = 1 mm.

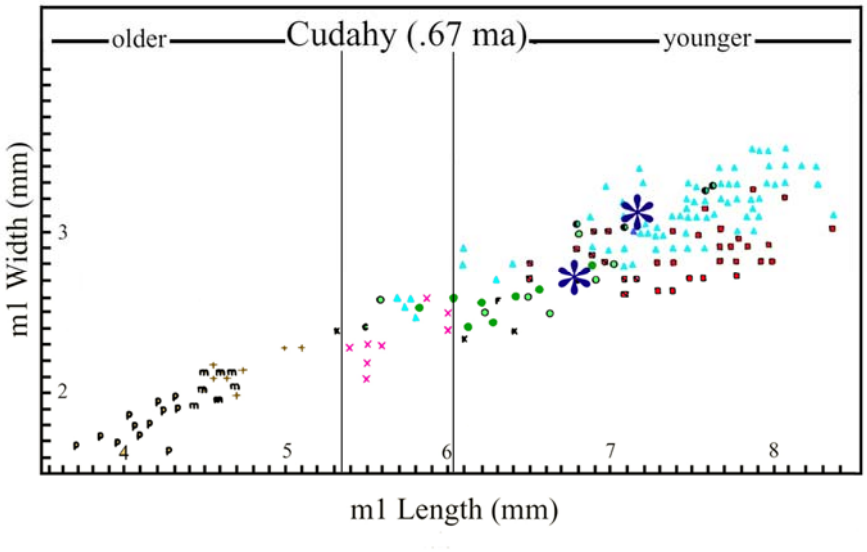


Figure 48. Length and width of the m1 in *Ondatra zibethicus* from Cathedral Cave, Nevada, plotted on the chronocline of Nelson and Semken (1970). Asterisks = Cathedral Cave specimens. Vertical lines bracket range of Cudahy specimens (= pink x).

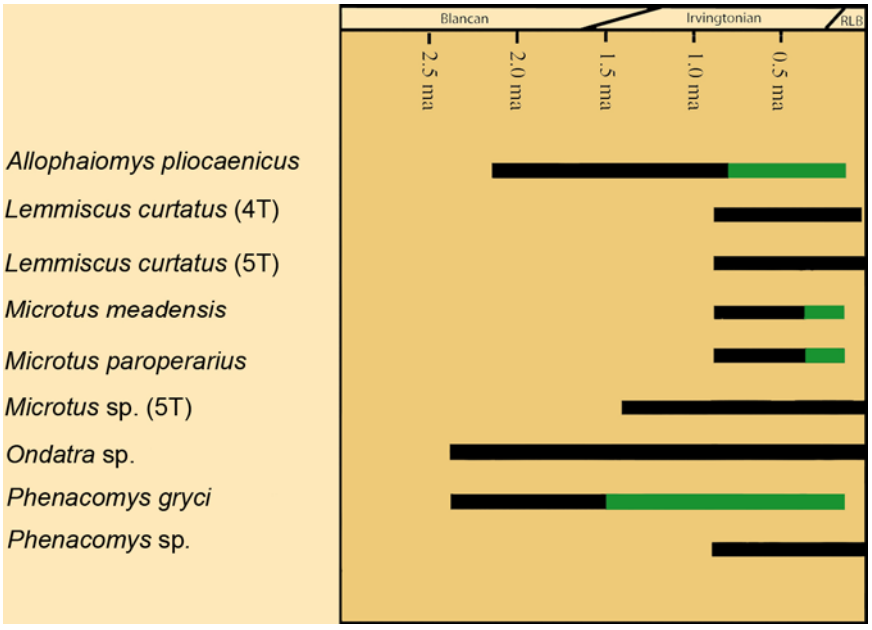


Figure 49. Chronologic distribution of arvicoline taxa identified from Cathedral Cave, Nevada. Color change signifies ranges with the addition of Cathedral Cave data.

Figure 50. Biochronologic provinces of North America based on arvicoline rodents. Follows Fejfar and Repenning (1992). Modified from Bell (2000).

CHAPTER 4: ARVICOLINE RODENTS, CAVE DEPOSITS, AND CHRONOLOGIC COMPLEXITY: A CASE STUDY FROM SMITH CREEK CAVE, NEVADA

INTRODUCTION

Smith Creek Cave (SCC) is a large rock shelter (~ 50 m x 18 m x 30 m) located at the mouth of Smith Creek Canyon in the northern Snake Range of eastern Nevada. Since 1925 several archeological and paleontological excavations were conducted at the site with the most recent field research efforts taking place in 1968, 1971, and 1974 (see summaries in Bryan, 1979 and Mead et al., 1982). Publications addressing the vertebrate fauna from the cave include the type descriptions of *Oreamnos harringtoni* (Stock, 1936), *Spizaetus willetti* (Howard, 1935), and *Teratornis incrediblis* (Howard, 1952). Additional reports provided a discussion of the herpetofauna (Brattstrom 1958, 1976), a summary faunal list (Goodrich 1965), a mammalian faunal list (Miller, 1979), a detailed review of the late Pleistocene/Holocene specimens known from multiple sites in Smith Creek Canyon (Mead et al., 1982), and additional records of arvicoline rodents (Mead et al., 1992; Bell and Mead, 1998).

Early reports on fossils from Smith Creek Cave (e.g., Stock 1936) provided limited data regarding site stratigraphy or age control (Mead et al., 1982). The primary chronologic framework for the site was established in conjunction with archeological investigations. Nineteen radiocarbon dates taken on a variety of materials place much of the Smith Creek Cave deposit within the late Pleistocene-Holocene (Bryan, 1979). Dated materials range in age from 28,650±760 yr B.P. to 1675±90 yr B.P. (Bryan, 1979).

In conjunction with a separate research project focused on the biochronology of arvicoline rodents (voles, lemmings, and muskrats) from Cathedral Cave, another cave deposit situated directly across Smith Creek Canyon, I examined arvicoline rodent specimens collected from Smith Creek Cave. Arvicoline rodents are important biochronologic tools that often are used to bracket the age of fossiliferous deposits lacking other forms of age control (see Bell, 2000, for review). Because of the proximity of the two sites (~ 1 km) and the presence of a diverse arvicoline rodent assemblage at Cathedral Cave (Bell and Barnosky, 2000; Bell et al., 2004a; Jass, 2005), a detailed re-examination of the arvicoline rodents from Smith Creek Cave was warranted.

My study of the Smith Creek Cave arvicoline specimens yielded unexpected results, including the identification of a greater diversity of taxa than previously recognized. The purposes of this paper are to provide a comprehensive description of the arvicoline rodent taxa known from Smith Creek Cave and to discuss the known chronologic distribution of these taxa with respect to their distribution within the sedimentary sequence of Smith Creek Cave. I also briefly discuss the potential implications of this arvicoline rodent fauna in the context of the complex nature of cave deposits.

STUDY MATERIALS

I examined 296 lower first molars (m1) from arvicoline rodents collected from Smith Creek Cave. With one exception (noted below), all specimens discussed here are curated at the Nevada State Museum in Carson City. Prior to this report none of the Smith Creek Cave arvicoline specimens housed at the Nevada State Museum were

uniquely numbered or curated independently from one another or from the other faunal remains. Therefore, I was not able to provide re-evaluations of the specific specimens or abundance data listed in previous reports (Miller, 1979; Mead et al., 1982). Individual specimens presented here were assigned permanent, unique numbers preceded by the prefix 'SCCAR' (= Smith Creek Cave Arvicoline Rodent). Appendix 6 summarizes specimens examined for this chapter.

There was some inconsistency in the labeling of bags containing faunal remains from the site. With the aid of original field notes housed at the Nevada State Museum, I was able to clarify the provenience of specimens examined in this study within described stratigraphic profiles of the cave deposits (Bryan, 1979). All but twelve of the specimens I examined were recovered from a single sedimentary stratum of reddish-pink silt that was overlain by human artifact-bearing sediments (Appendix 7). Evidence to suggest human activity during the time of deposition of the reddish-pink silt is equivocal (Bryan, 1979).

The color of this particular stratum was described in a variety of manners (reddish-brown, reddish-pink, red, and pink) on both bone bag labels and in the literature (Bryan, 1979; Miller, 1979). The sedimentary level described as a reddish-brown silt deposit from the rear of the cave may stratigraphically correlate with a deposit of rubble and pink silt from near the cave mouth (Bryan, 1979), although this was neither demonstrated in previous reports nor is it clearly evident from exposed trenches in the cave. Bone was reported as being absent from lower sedimentary levels near the mouth of the cave (Miller, 1979), and all specimens I examined that are labeled as having come from either a red silt, a reddish-pink silt, a reddish-brown silt, or a 'pink layer' come from

test pits from the rear of the cave (Fig. 51). Therefore, I considered bags of curated bones ascribed to a red silt, reddish-pink silt, reddish-brown silt, or 'pink layer' to be stratigraphically equivalent. Arvicoline teeth and other bone remains from that sedimentary level are stained red in appearance in contrast to the whitish appearance of bone from upper portions of the deposit. The remaining specimens either came from a layer of rodent dung and brown silt situated stratigraphically above the reddish-pink silt (five specimens) or were of unknown stratigraphic provenience due to limitations in data associated with the specimens (seven specimens).

The described rubble/pink silt from the front of the cave and the reddish-brown silt deposit from the rear of the cave both lacked definitive evidence of cultural materials, and only a single radiocarbon date is known from either of these strata (Bryan, 1979). A radiocarbon age of 28,650 ± 760 ^{14}C yr BP. (Tx-1639) was based on a sample of bone collagen extracted from an unidentifiable bone fragment collected in the reddish-brown silt near the rear of the cave (Bryan, 1979). Given the nature of the sample (collagen) and confusion surrounding the provenance of the sample, this date provides only a rough estimate of the age of the reddish-pink silt zone (Mead et al., 1982). An age of 12,600 ± 170 ^{14}C yr BP. (A-1565) taken on pine needles from a zone overlying the pink silt near the front of the cave represents the next oldest age known from the site (Bryan, 1979). All other radiocarbon dates from the site are younger and most are associated with archeological materials (Bryan, 1979; Thompson, 1985).

I used the publicly accessible, online radiocarbon calibration program at http://www.radiocarbon.LDEO.columbia.edu/ to calibrate calendar ages for radiocarbon dates that were relevant to research presented here (Fairbanks et al., 2005). Calibrated

ages for the radiocarbon dates of 28,650 ± 760 ^{14}C yr BP. and 12,600 ± 170 ^{14}C yr BP were 34,039 ± 799 yr BP and 14,627 ± 277 yr BP, respectively. Accepting the possibility that the silt zones from the front and rear of the cave are correlated, they are potentially 20 thousand years older than overlying archeological deposits on the basis of radiocarbon chronology.

IDENTIFICATION METHODS

Taxonomic identifications of arvicoline m1s from Smith Creek Cave were based on comparisons with the m1s of extant and extinct arvicolines and descriptions of those taxa from the literature. Initial examination and identification of specimens was conducted using 10x magnification. Subsequent verification of the identifications was conducted under a binocular microscope at varying magnification levels.

Dental terminology discussed here and depicted in Figure 52 follows Bell and Jass (2004). The m1 of arvicolines may be rooted or unrooted depending on the taxon. All arvicoline m1s have a posterior loop, a series of enamel-bound triangles, and an anterior cap (Fig. 52). Open spaces between triangles are referred to as reentrant angles and may or may not be filled with cementum depending on the taxon. Triangles are numbered sequentially from back to front, and abbreviated references to individual triangles are used in the text below (e.g., T1; see Fig. 52). 'Primary wings' refers to T4 and T5 whereas 'secondary wings' refers to T6 and T7 (Fig. 52).

On the illustrations, enamel bands are shown in white, dentine is in black, and cementum is stippled. Broken or missing portions of the teeth are depicted with a series of horizontal lines. The closure of individual triangles relative to each other or the

anterior cap was categorized as being open, pinched, exhibiting incipient closure, or closed following Bell and Barnosky (2000). Open or confluent triangles had openings that exceeded three enamel band-widths. Pinched triangles exhibited openings between two and three enamel band-widths. Triangles with incipient closure had openings between one and two enamel band-widths. Closed triangles had openings of less than one band-width of enamel.

RESULTS

The four arvicoline rodent taxa identified from Smith Creek Cave are *Microtus meadensis, Microtus paroperarius, Microtus* sp. (not *Microtus meadensis* or *Microtus paroperarius*), and *Lemmiscus curtatus*. Both *Microtus* sp. and *Lemmiscus curtatus* are characterized in the fauna by multiple morphotypes. These include the four-triangle form of *Lemmiscus curtatus*, a morphotype that persisted only into the early Holocene (Barnosky and Bell, 2003; Bell and Jass, 2004). Identifying characteristics and abundance of each identified taxon are discussed below.

Two hundred thirty-nine specimens (80.7%) were identified as *Microtus* sp., making it the dominant taxon in the Smith Creek Cave deposit. These specimens exhibit greater labial-lingual length in T1 than T2, a character that can be used to distinguish *Microtus* from *Lemmiscus* (Barnosky and Rasmussen, 1998). Specimens identified as *Microtus* sp. in this paper are characterized by the presence of at least five closed, alternating triangles, distinguishing them from both *Microtus paroperarius* and *Microtus meadensis*. Previous reports on the Smith Creek Cave fauna separated *Microtus* cf. *M. montanus* (Goodrich, 1965; Miller, 1979) and *Microtus* cf. *M. longicaudus* (Mead et al.,

1982) as distinct from other specimens referred to *Microtus* sp. Given the current state of knowledge regarding identification of m1s of *Microtus* at the species level (see Bell et al., 2004a, for discussion), there is no morphological basis for the identification of *Microtus* cf. *M. montanus* and *Microtus* cf. *M. longicaudus* from Smith Creek Cave. I consider previous reports of these taxa to be synonymous with *Microtus* sp. as reported here.

Lower first molars of *Microtus* show high levels of variation (e.g., Paulson, 1961; van der Meulen, 1978; Guilday, 1982; Weddle and Choate, 1983; Martin, 1987, 1993; Harris, 1988; Barnosky, 1990, 1993; Pfaff, 1990; Bell and Repenning, 1999; Gordon, 1999), and specimens recovered from Smith Creek Cave are no exception. Ten morphologic variants of *Microtus* sp. were recovered. These are a five-triangle form with well-developed secondary wings that are confluent with the anterior cap (196 specimens; see Fig. 53A), a five-triangle form where triangles 1 and 2 are confluent with one another (one specimen), a five-triangle form where T6 is pinched from T7 and anterior cap (16 specimens), a five-triangle form where T6 is pinched from T7 but T7 is closed from the anterior cap (one specimen), a five-triangle form where the T6 exhibits incipient closure from T7 and anterior cap (three specimens), a five triangle form where T6 and T7 are confluent but are closed from the anterior cap (three specimens; Fig. 53B), a five triangle form where T6 and T7 are confluent but are pinched from the anterior cap (one specimen), a five triangle form where T6 and T7 are confluent but exhibit incipient closure from the anterior cap (one specimen), a six triangle form where T6 is closed from a confluent T7/anterior cap complex (15 specimens), and a seven triangle form where both secondary wings (T6 & T7) are closed (one specimen; Fig 53C). One specimen (SCCAR-203) had T5 pinched from the secondary wings/anterior cap in occlusal view,

but T5 was closed in ventral view. I conservatively identified this specimen as *Microtus* sp. rather than *M. paroperarius* (see description below). A single specimen (SCCAR-115) of the common five-triangle form has unique morphology on T4 (Fig. 53D).

Two of the 296 specimens examined for this study (< 1%) were identified as *Microtus meadensis*. Specimens of *Microtus meadensis* from Smith Creek Cave are characterized by the presence of three closed, alternating triangles (Triangles 1-3), followed by confluent primary wings (Triangles 4 and 5) that are closed from the secondary wings (Triangles 6 and 7) and anterior cap (Fig. 54A). The enamel of the m1 is positively differentiated, where the leading edges of triangles retain thicker enamel than on the posterior edges. Cementum is present in the re-entrant angles. This m1 structure is similar to that found in some extant *Microtus quasiater* and *Microtus pinetorum* (Repenning, 1983; Zakrzewski, 1985a). Other authors discussed features that characterize the m1 of *Microtus meadensis* and other extant taxa that exhibit similar morphologies (Martin, 1987; Harris, 1988). However, the frequency of distinct m1 morphologies is undocumented for populations of *Microtus meadensis* and similar, extant taxa.

Three of the 296 specimens (1.0%) were identified as *Microtus paroperarius*. Specimens of *Microtus paroperarius* from Smith Creek Cave have four closed, alternating triangles, followed by a well-developed fifth triangle that is variably confluent with the secondary wings and anterior cap (Fig. 54B, C). Two of these specimens exhibit a state where the fifth triangle is pinched from the secondary wings (e.g., Fig. 54B). In one specimen (SCCAR-212), the fifth triangle is broadly confluent with the secondary wings (Fig. 54C). This variation is consistent with that seen in other samples of *Microtus*

paroperarius, but is also known to be similar or identical to the living *Microtus oeconomus* (van der Meulen, 1978). Additionally, this morphology is known to occur in very low percentages in some other extant species of *Microtus* (Bell and Repenning, 1999).

Fifty of the 296 arvicoline specimens (16.9%) were identified as *Lemmiscus curtatus*. The only previous report of *Lemmiscus* from Smith Creek Cave was based on specimens collected from a back-dirt pile in the cave (Bell and Mead, 1998). I identified both four- and five-triangle forms (Fig. 55). The five-triangle form is most common, comprising 45 of the 50 specimens (90%) of *Lemmiscus curtatus* (Fig. 55A). These specimens are characterized by the presence of five closed triangles and a well-developed T6 that is confluent with the anterior cap. They exhibit equal (or roughly equal) labial-lingual lengths in T1 and T2, a character that distinguishes them from *Microtus*, which has a labial-lingual width of T1 that is larger than T2 (Barnosky and Rasmussen, 1998). Five specimens represent a four-triangle form where the fourth triangle is either confluent, pinched, or has incipient closure with respect to T5 (Figs. 55B, C).

Four-triangle forms of *Lemmiscus curtatus* are noteworthy because that morphology is not known to occur in extant populations of sagebrush voles (Bell and Barnosky, 2000; Barnosky and Bell, 2003) and loss of this morphotype may represent one of the few small mammal 'extinction' events near the early Holocene (Bell and Jass, 2004). Smith Creek Cave represents only the seventh locality known to preserve specimens of *Lemmiscus curtatus* that have a four-triangle morphology (other localities were reviewed by Bell and Jass, 2004). Given the fact that three of the localities containing a four-triangle form of *Lemmiscus curtatus* occur in or near the vicinity of

Smith Creek Canyon, it seems a strong possibility that other Pleistocene localities in the vicinity (e.g., Crystal Ball Cave) may also preserve this morphotype.

In addition to the specimens reported here, two other arvicoline rodent taxa were reported from Smith Creek Cave. A single specimen (NAUQSP 17910) of *Phenacomys* that was collected from a back-dirt pile in Smith Creek Cave is housed at the Laboratory of Quaternary Paleontology, Northern Arizona University. The specimen was not examined for this study but was described and illustrated by Mead et al. (1982; as *Phenacomys* cf. *P. intermedius*) and Repenning and Grady (1988; as *Phenacomys albipes*).

Specimens of *Mictomys borealis* were reported from both Cathedral Cave and Smith Creek Cave (Mead et al., 1992). The record from Cathedral Cave consisted of multiple specimens, but only a single M2 was reported from Smith Creek Cave. A subsequent re-examination of arvicoline rodents from Cathedral Cave (Bell, 1995) revised the identification of *Mictomys borealis* but did not address specimen from Smith Creek Cave. During the course of this study, no additional specimens of *Mictomys* were found in the Smith Creek Cave material housed at the Nevada State Museum. In the absence of additional specimens of *Mictomys* from Smith Creek Cave (e.g., m1s) that would allow for a more confident taxonomic placement, I consider the single record reported by Mead et al. (1992) to be *Mictomys* sp.

DISCUSSION

Variation in the m1 of Microtus

Variation in the dentition of extant and fossil *Microtus* is common and widely recognized within species (e.g., Paulson, 1961; van der Meulen, 1978; Guilday, 1982; Weddle and Choate, 1983; Martin, 1987, 1993; Harris, 1988; Barnosky, 1990, 1993; Pfaff, 1990; Bell and Repenning, 1999; Gordon, 1999). Because morphologies that resemble *Microtus meadensis* and *Microtus paroperarius* are known from extant populations, the possibility that the Smith Creek Cave specimens represent population variants of extant taxa must be acknowledged. I am hesitant to accept such an interpretation because of the presence of similar morphotypes found in association with other extinct taxa (e.g. *Mictomys* cf. *M. meltoni* or *M. kansasensis*) at Cathedral Cave, situated across the canyon from Smith Creek Cave, and observations of arvicoline m1s in the back dirt pile of Smith Creek Cave,.

Both *Microtus meadensis* and *Microtus paroperarius* are known in higher percentages (2.4% and 6.5%, respectively) relative to the total number of arvicolines from nearby Cathedral Cave (see Chapter 3). Independent age estimates indicate a maximum age between 90 ka and 182 ka for the Cathedral Cave fauna (see Chapter 3). The data from Cathedral Cave indicate the presence of both taxa in Smith Creek Canyon during the Pleistocene. Although the abundance of these taxa in Smith Creek Cave is lower than in Cathedral Cave, it seems reasonable to infer that *Microtus meadensis* and *M. paroperarius* may be represented by the morphologies described above.

The recognition of abundant arvicoline m1s in the backdirt pile of Smith Creek Cave (Jass, personal observation; Mead et al., 1982, 1992; Bell and Mead, 1998) suggests that many excavated arvicoline specimens were missed in the original collection process. As pointed out by Miller (1979), much of the osteological material was recovered using ¼-inch (6.35 mm) mesh screens and this likely contributed to the loss of many arvicoline specimens. As a result, the percentages of various morphologies presented in this report are potentially biased and increase my reluctance to classify the low percentages of *Microtus meadensis* and *Microtus paroperarius* morphotypes as morphological variants of extant species of *Microtus*. At the least, the use of this taxonomy calls attention to the specimens and the variation in the m1 of *Microtus* from Smith Creek Cave. Future research at Smith Creek Cave and/or further evaluation of dental variation in *Microtus* may alter this taxonomic interpretation.

Biochronology and the Arvicoline Rodents of Smith Creek Cave

Arvicoline rodents are known from the late Miocene-Recent in North America. Rapid rates of reproduction known in extant arvicolines along with a highly diversified and rapidly evolving dentition underscore the significance of this group in late Tertiary through Quaternary biochronology. Recognition of the importance of arvicoline rodents as biochronological markers in terrestrial deposits began with research in the Meade Basin of Kansas (e.g., Hibbard, 1944, 1949). Arvicoline biochronology advanced significantly in the 1970s and 1980s with the work of Martin (1979) and Repenning (1978, 1980, 1984, 1987) who developed conceptually and contextually distinct temporal divisions for the continent (Bell, 2000). Ultimately, relative chronologic frameworks are

subject to change with the addition of new data and/or independent dating methods and this is reflected in recent work concerning the chronological distribution of arvicoline rodent taxa (e.g., Bell and Barnosky, 2000; Bell et al. 2004a, 2004b).

Consideration of the arvicoline rodent fauna from Smith Creek Cave in a broad biochronologic context raises interesting issues. With the exception of *Microtus paroperarius* and *M. meadensis*, the arvicoline rodent taxa identified from Smith Creek Cave are known to occur as recently as the early Holocene (four-triangle morphotype of *Lemmiscus curtatus*) or as components of the extant biota (*Lemmiscus curtatus*, *Microtus* sp., *Mictomys* sp., and *Phenacomys* sp.). However, records of *Phenacomys* and *Mictomys* at Smith Creek Cave and in central portions of the Great Basin represent disjunct geographic occurrences given the known modern distribution of these taxa in areas to the north, east, and west of the Great Basin (Grayson, 1981; Mead et al., 1982, 1992).

The specimens of *Microtus paroperarius* and *Microtus meadensis* identified from the reddish-pink silt stratum were collected from different arbitrary levels within the stratum. Unfortunately, I was not able to reconstruct confidently the vertical relationships of the specimens or arbitrary levels because the provenience data varied in scope and detail. I was not able to resolve the differences in data in a satisfactory manner, and I consider all taxa from the reddish-pink silt to be derived from a single stratigraphic level that has an associated radiocarbon age of 28,650 ± 760 ^{14}C yr BP.

One of the two *Microtus meadensis* specimens came from a layer of rodent dung and brown silt that was situated stratigraphically above the reddish-pink silt. There are no radioisotopic dates associated with this layer, but the color of this specimen and

specimens of *Microtus* sp. from the same level suggest that they were mixed from the reddish-pink silt zone.

The known chronologic distribution of arvicoline taxa included in this report is presented in Table 15. Recent biochronologic summaries bracket the known age distributions of *Microtus paroperarius* from ~840 Ka to 252 ± 30 Ka and *Microtus meadensis* from 820 Ka to 252 ± 30 Ka (Bell et al., 2004a, 2004b). These chronologic ranges do suggest an older age for fossils from the reddish-pink silt level at least; between 820 Ka and 146.02±2.584-151.2±4.4 Ka based on maximum and minimum ages of all arvicolines from the site and biochronologic data from Cathedral Cave. Conversely, there is no explicit reason to rule out an alternate interpretation whereby Smith Creek Cave contains chronologic range extensions for both *Microtus paroperarius* and *Microtus meadensis* to as recently as 28,650 ± 760 ^{14}C yr BP. As mentioned above, the radiocarbon date for the reddish-pink silt level was based on bone collagen. In the absence of additional radioisotopic testing using newer collagen extraction techniques or testing on more reliable materials (e.g., charcoal, twigs; see Meltzer and Mead, 1985 for discussion), such a dismissal would be premature. A third possibility would be that both biochronologic and radioisotopic (^{14}C yr BP) age assignments are incorrect and another age represents the 'true' age or ages of the red silt zone. A final possibility is that the specimens represent population variants of *Microtus* and are chronologically uninformative.

In many respects, the chronologic quandary regarding arvicoline rodent biochronology versus radioisotopic data from Smith Creek Cave is similar to that

encountered at Cathedral Cave, a paleontological site situated directly across the canyon from Smith Creek Cave, where there were significant differences between biochronologic age estimates and initial radioisotopic ages for the site (see Mead et al, 1992; Bell, 1995; Jass, 2005). A considerable effort has since gone towards resolving chronological discrepancies at Cathedral Cave (Chapter 3). Similar efforts would be necessary to resolve age discrepancies at Smith Creek Cave and are at present beyond the scope of this paper. However, even in the absence of a resolution to the chronologic problem identified here, my investigations at Smith Creek Cave nicely illustrate and re-emphasize challenges associated with research on archeological and paleontological remains collected from cave deposits.

Complexity in Cave Deposits

Caves represent complex depositional settings (Sutcliffe, 1970; Gillieson, 1996) and Smith Creek Cave is no exception. Multiple processes (anthropogenic, biologic, chemical, and geologic) contributed to the deposition of sediments at the site, and likely served to alter and modify the deposit. In a sense, sedimentary deposits like the ones preserved in Smith Creek Cave represent a microcosm of the larger-scale sedimentary processes that shape larger, open-air deposits. Some geologic features observed on broad scales in outcrop (e.g., unconformities) are just as likely to occur within sedimentary deposits within caves. The main difference between sedimentary processes impacting cave deposits versus larger, open-air, sedimentary systems lies in the seemingly greater magnification of the those processes for creating complex depositional systems in a spatially restricted area. When geologic processes, such as bioturbation, occur in the

restricted geographic space of a cave deposit, the complexity of the deposit potentially increases more rapidly than a similar process occurring over a larger area (e.g., extensive, open-air deposits).

A strictly biochronologic age estimate (based on biochronologic data from Cathedral Cave and elsewhere) for the reddish-pink silt zone would suggest a hiatus in deposition of $\geq$ 62 kyr but $\leq$ 136 kyr between the reddish-pink silt and overlying archeological deposits at Smith Creek Cave. That range of numbers applied to open-air deposits does not seem particularly daunting or improbable. Within the context of a cave deposit this range represents a large number of years between deposition of the reddish-pink silt and deposition of the overlying, relatively continuous, chronologic framework.

Other researchers previously showed that caves may contain multiple unique deposits of differing ages across distinct portions of a cave (e.g., Lundelius, 1985b). Yet I know of no North American sites reported to contain sediments of widely disparate ages in vertical succession. In fact, only a handful of cave deposits (e.g., Fyllan Cave [Winkler and Gose, 2003], Porcupine Cave [Barnosky, 2004a], SAM Cave [Rogers et al., 2000], Salamander Cave [Mead et al., 1996]) in the western United States are definitively documented to contain fossil remains that pre-date the terminal Pleistocene. In contrast, some regions of Europe have caves that contain mammal fossils of Pliocene age (Kurtén, 1968).

This may represent something 'real' about the nature of fossil preservation in cave deposits or reflect a relatively short (geologically-speaking) existence of such deposits in western North America. Methodological limitations for attaining accurate external age control on sites that pre-date radiocarbon (i.e., < 60,000 yr B.P.) are problematic and may

be contributing to a skewed understanding of the age of fossils preserved in North American caves. However, I hypothesize that it may be (in part) an artifact of the abundance of cave deposits that contain terminal Pleistocene-Recent sediments and the heavy research emphasis from both paleontologists and archeologists on questions relating to deposits of this age. Perhaps the paucity of sites containing pre-terminal Pleistocene sediments is partially an artifact of research bias or interest. Whatever the reason, the presence of *Microtus paroperarius* and *Microtus meadensis* at Smith Creek Cave should serve as a reminder that caves are complex depositional systems and that researchers must at least be aware of the potential for significant chronologic unconformities in the vertical sequences excavated from them.

CONCLUSIONS

Smith Creek Cave contains a more diverse arvicoline rodent fauna than previously reported. Notable additions to the arvicoline record from Smith Creek Cave include *Microtus paroperarius*, *Microtus meadensis*, and a four-triangle morphotype of *Lemmiscus curtatus*. The identification of *Microtus paroperarius* and *Microtus meadensis* suggest the possibility of an older age for the reddish-pink silt zone than was indicated by radiocarbon dating. Although definitive chronologic reconciliation between biochronologic and radioisotopic data is not possible at present, the presence of these arvicoline taxa in the context of the known stratigraphy/chronology for the site re-emphasizes the high potential for complexity in cave deposits. At the least, the identification of these taxa illustrates potential problems with the recognition of

morphologic variation in fossil taxa. Additional radioisotopic dating (e.g., AMS on bone collagen and charcoal) and further fieldwork focused on micro-sampling the reddish-pink silt zone might help clarify the stratigraphic and chronologic distribution of *Microtus meadensis* and *Microtus paroperarius* within the sedimentary sequence of Smith Creek Cave. Re-screening of the backdirt piles for arvicoline specimens would also produce additional materials that could be used to further evaluate the rarity of m1s of *Microtus meadensis* and *Microtus paroperarius.*

Table 15. The known chronologic distribution of arvicoline rodent taxa recovered from Smith Creek Cave (from Bell et al., 2004a, b). The chronologic distribution of *Phenacomys* sp. represents those forms that are distinct from the morphologically unique *P. gryci*. *Microtus* sp. represents those taxa that have a minimum of 5 closed, alternating triangles on the m1.

Taxon	Earliest Known Occurrence	Latest Known Occurrence
Lemmiscus curtatus (4T)	840 Ka	~9.5 Ka
Lemmiscus curtatus (5T)	840 Ka	Extant
Microtus sp.	1.4 Ma or ~840 Ka	Extant
Microtus meadensis	820 Ka	252 ± 30 Ka
Microtus paroperarius	~840 Ka	252 ± 30 Ka
Mictomys sp.	2.5 Ma	Extant
Phenacomys sp.	~840 Ka	Extant

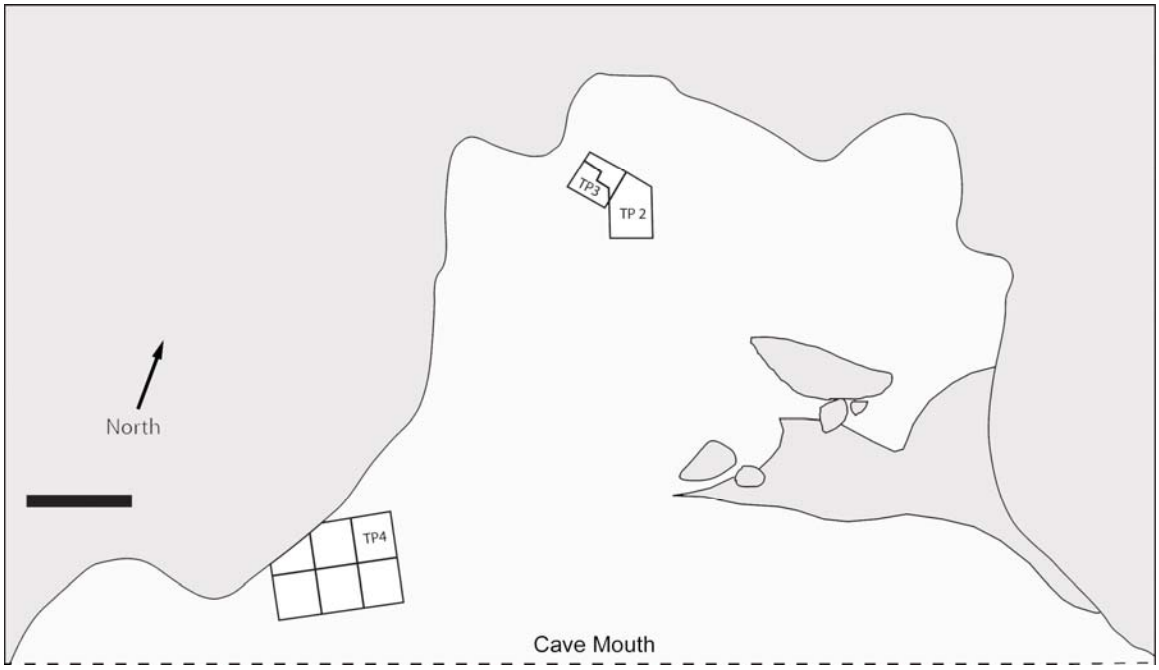


Figure 51. Simplified plan view map of Smith Creek Cave showing test pit areas (TP) that produced the fossils discussed in this report. Gray = bedrock. Scale bar = 5 m. Modified from Bryan (1979).

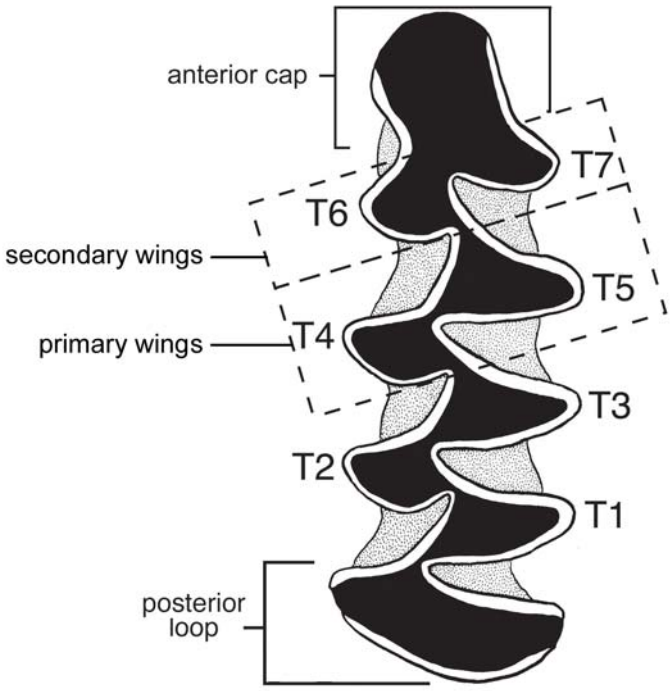


Figure 52. General structure and features of the lower first molar in arvicoline rodents showing position of primary and secondary wings. Modified from Bell and Jass (2004).

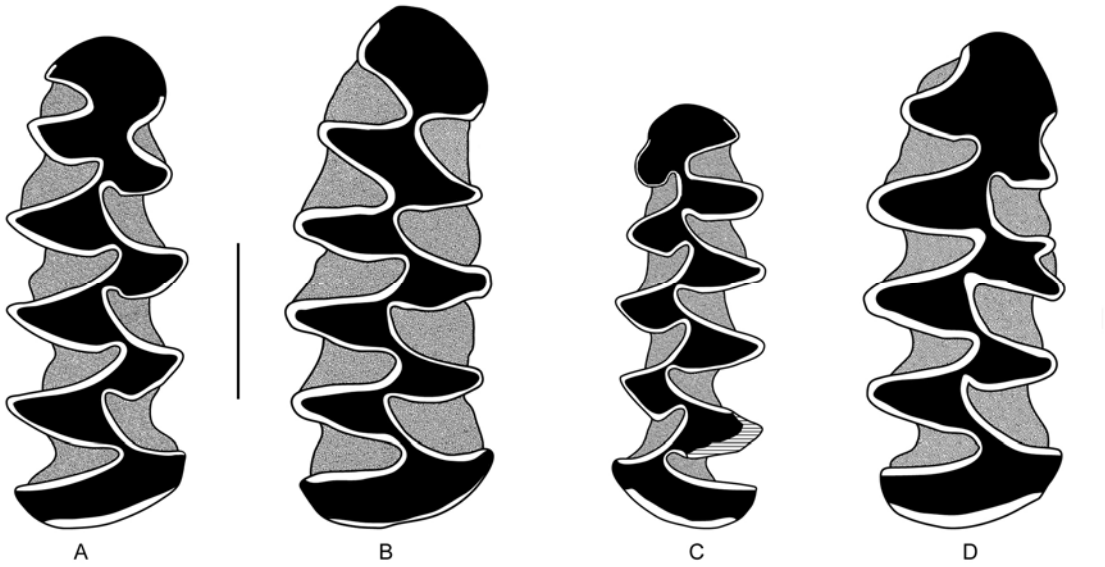


Figure 53. Variation in the morphology of *Microtus* sp. from Smith Creek Cave. A. *Microtus* sp. with five closed triangles (SCCAR-255). B. *Microtus* sp. with five closed triangles and secondary wings that are closed from the anterior cap (SCCAR-254). C. *Microtus* sp. with seven closed triangles (SCCAR-250). D. *Microtus* sp. with aberrant enamel pattern on T4 (SCCAR-115). Scale bar = 1 mm.

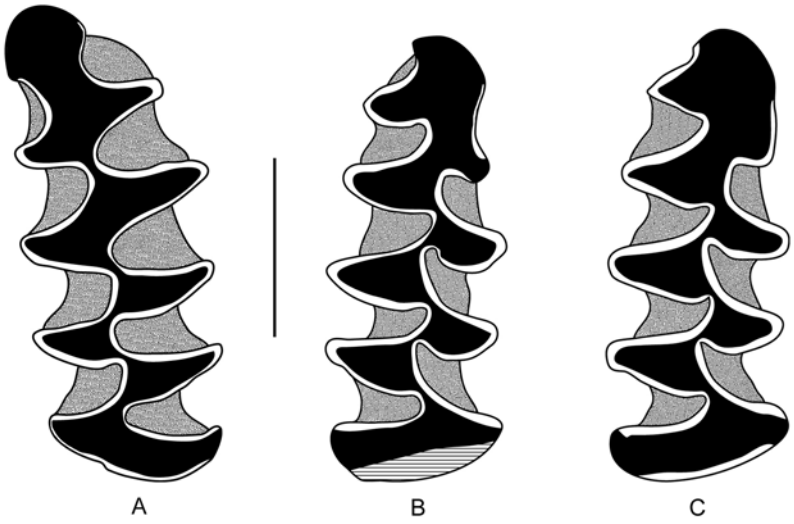


Figure 54. Specimens of *Microtus meadensis* and *M. paroperarius* from Smith Creek Cave. A = Left m1 of *M. meadensis* (SCCAR-27). B = Right m1 of *M. paroperarius* (SCCAR-25). C = Right m1 of *M. paroperarius* (SCCAR-212). Scale bar = 1 mm.

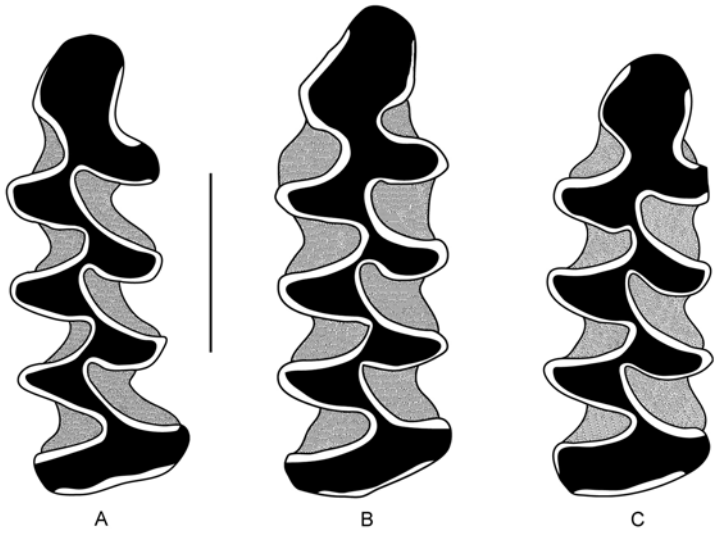


Figure 55. *Lemmiscus curtatus* from Smith Creek Cave. A. *Lemmiscus curtatus* with five closed triangles (SCCAR-261). B. *Lemmiscus curtatus* with four closed triangles (SCCAR-118). C. *Lemmiscus curtatus* with four closed triangles and a pinched T5 (SCCAR-106). Scale bar = 1 mm.

CHAPTER 5: *AZTLANOLAGUS AGILIS* AND OTHER LAGOMORPHS FROM CATHEDRAL CAVE

INTRODUCTION

A significant body of research on the fossil lagomorphs of the Great Basin is currently available in the literature, primarily as a result of efforts to understand mammalian biogeographic patterns in the region from the late Pleistocene to late Holocene. *Sylvilagus nuttalli* (Nuttall's cottontail), *Lepus townsendii* (white-tailed jackrabbit), and *Ochotona princeps* (North American pika) were included in Brown's (1978) classic study on montane mammal biogeography in the Great Basin. Subsequent research continued to emphasize the importance of Great Basin lagomorphs in biogeographic studies in the region (Mead et al., 1982; Thompson and Mead, 1982; Mead, 1987; Grayson 1993, 2000a, 2000b, 2005, 2006; Grayson and Livingston, 1993; Hafner, 1993; Mead and Spaulding, 1995; Mead and Grady, 1996). Here I present a systematic account of the lagomorphs from Cathedral Cave, Nevada, including the first Great Basin record of the extinct species, *Aztlanolagus agilis*. Additional discussion focuses on variation in the third lower premolars (p3) of lagomorphs from Cathedral Cave and potential circularity in the use of fossil lagomorph species in analyses of the natural history and paleobiology of Great Basin mammals.

Cathedral Cave (CC) is located on a north-facing slope at the mouth of Smith Creek Canyon, Nevada in the east-central Great Basin (Figure 1). Preliminary fieldwork at the site was conducted in 1989 and was intended to test the paleontological significance of the site (Bell, 1990). Initial age range estimates for portions of the

excavated fauna were maximally between 15,000 ± 200 yr and 24,600 ± 2100 yr B.P. based on uranium-series analyses (Bell, 1990). Subsequent analyses and research in the same region of the cave indicated an older age for the deposit (Bell, 1995; Bell and Barnosky, 2000; Bell et al., 2004; Jass, 2005; see Chapter 3). The most recent age estimate places lower portions of the deposit in a maximum age range of 146.02±2.584 ka to 151.2±4.4 ka (see Chapter 3). This age range is chronologically unique for the region. As a result, the Cathedral Cave fauna provides insight into taxonomic and biogeographic changes that occurred within the Great Basin prior to the latest Pleistocene.

MATERIALS AND METHODS

The lagomorphs described here were collected during a new excavation conducted at Cathedral Cave in 2003. The excavation consisted of a 1.5 m x 2 m area that was taken down to a maximum depth of 110 cm below an arbitrary datum, or roughly 76 cm below the surface of the deposit. The excavation was stopped at what appeared to be large blocks of roof spall sitting directly on the bedrock floor of the cave. Excavation levels were removed in arbitrary 5-cm intervals except where natural sedimentary levels could be removed as distinct units. All excavated sediments were bagged, labeled, and transported for screen-washing and sorting.

Screen-washing was conducted at the Vertebrate Paleontology Laboratory of the Texas Natural Science Center and the Laboratory of Quaternary Paleontology at Northern Arizona University. All sediments were washed through nested pairs of screens (3.175

mm and 0.7 mm-mesh). Washed sediments were allowed to air dry and then were either sorted immediately for fossils or bagged for future sorting. Additional details concerning excavation and screen-washing methods were presented in Chapter 1.

The sample of 183 lagomorph fossils presented here comes from the total sample (226 bags) of sorted coarse mesh (3.175 mm) sediments and a single bag of fine mesh sediments (0.7 mm) from each unique provenience level. Specimens are housed at the Vertebrate Paleontology Laboratory of the Texas Memorial Museum (TMM) under the locality number 43693. Each identified specimen was assigned a unique specimen number (e.g., TMM 43693-1).

The majority of lagomorph specimens from Cathedral Cave consist of isolated teeth. Patterns of evolution and taxonomic identification in lagomorphs are usually based at least partially on changes in the enamel pattern of the p3 (e.g., White, 1984, 1987, 1991a, 1991b). In this study I included isolated p3s, dentaries that retain the p3, and a few edentulous dentaries that retained characteristics that allowed for a reliable taxonomic identification. Other recovered teeth, skull fragments, and jaw fragments were not included in the current analysis but are available for future study.

The p3 in lagomorphs is characterized by patterns of enamel-banded dentine that range from simple to complex, and cementum-filled re-entrant folds. In many leporid teeth the enamel folds appear wrinkled or crenulated and the degree of crenulation is sometimes invoked for purposes of identification, particularly for extinct taxa (Ramos, 1999a). Evaluations of the tooth patterns in individual specimens were conducted under a binocular microscope. Maximum occlusal length and width measurements of the p3 were taken using an occular micrometer on a binocular microscope.

SYSTEMATIC PALEONTOLOGY

The following summary of the lagomorphs from Cathedral Cave, Nevada is based on results of the 2003 excavation. Taxonomy and classification above the species level follows McKenna and Bell (1997).

LAGOMORPHA Brandt, 1855

OCHOTONIDAE Thomas, 1897

Ochotona Link, 1795

Ochotona sp.

Referred Specimens-See Appendix 8.

Description-The p3s of *Ochotona* sp. from Cathedral Cave are all of similar size (Figure 56) and are characterized by the presence of at least three enamel reentrant folds (Figure 57a,b). All three folds (anterointernal, anteroexternal, and posteroexternal) are simple and lack the crenulated enamel folds seen in many leporid species. In some specimens (e.g., TMM 43693-1857) I noted only weak development of the anterointernal reentrant, a character that is similar to the '*Ochotona* sp. near Trout Cave form' identified at Porcupine Cave, Colorado (Mead et al., 2004). Several specimens retained at least some development of a fourth, posterointernal reentrant fold. In one of these specimens (TMM 43693-1856) a posterointernal reentrant fold appears strongly developed in both occlusal and ventral views (Fig. 57c).

Dentaries identified as *Ochotona* that lacked the p3 were identified on the basis of diminutive size and general shape similarity to specimens of modern pikas. Where

possible, the shape of the m3 or m3 socket was evaluated because this feature is anteroposteriorly shorter in ochotonids, but triangular in leporids (Heaton, 1985).

Discussion-Two living species of pika (*O. collaris* and *O. princeps*) occur in North America today. *Ochotona collaris* is geographically restricted to portions of Alaska and northwestern Canada while *O. princeps* inhabits portions of southwestern Canada and the western United States (Wilson and Ruff, 1999). Two extinct pikas are known from North America. *Ochotona spanglei* is known from late Miocene-early Pliocene deposits in Oregon (Shotwell, 1956). Another extinct form, *O. whartoni*, represents a larger form and is known only from Pleistocene deposits in Alaska and Canada (Guthrie and Matthews, 1971; Mead and Grady, 1996).

The average length of the p3 in Cathedral Cave specimens was 1.23 mm (n = 75; SD = 0.11; range = 1.0-1.5) and the average width was 1.32 mm (n = 74; SD = 0.16; range = 1.0-1.6). Presently, available size data for the dentition of North American *Ochotona* relates to alveolar lengths (e.g., Mead et al., 2004).

The degree of variation in morphometric and qualitative characters of the p3 in fossil and extant pikas of North America has not been explicitly evaluated. There is some indication that morphological variants occur in the fossil record (e.g., Mead et al., 2004), but the taxonomic level at which that variation is expressed remains unclear at present. It is possible that most, if not all, of the specimens from Cathedral Cave represent *Ochotona princeps*. However, identification as *O. princeps* currently requires an explicit assumption that fossils of *Ochotona* occurring within or near the modern range of *O. princeps* are referable to that species. That assumption could potentially render circular the use of Cathedral Cave specimens in subsequent biogeographic analyses of species.

As a result, I restrict my identifications to *Ochotona* sp. but provide an illustration of a specimen (TMM 43693-1856) with a morphotype that may fall outside of the natural range of variation in the p3 of *Ochotona princeps* (Figure 57c).

TMM 43693-1856 has a well-developed postero-internal fold that is unique with respect to other North American pika records. A review of the phylogeny and evolution of ochotonids included an illustration of a p3 of *Ochotona antiqua* that exhibits four reentrant folds as in TMM 43693-1856 (Erbajeva, 1994). *Ochotona antiqua* is known only from late Miocene-early Pliocene deposits in the Old World (Erbajeva, 1994). Until a thorough review of variation in the p3 of New and Old World species of *Ochotona* is available, I am hesitant to assign TMM 43693-1856 to any particular species. The occurrence of this p3 morphology from Cathedral Cave could represent either a new species, a new record of an Old World species, or may fall within the natural, but as yet undocumented, range of variation in extant North American pikas.

LEPORIDAE

Aztlanolagus Russell and Harris, 1986

Aztlanolagus agilis Russell and Harris, 1986

Referred Specimens-See Appendix 8.

Description-The p3s of *Aztlanolagus agilis* are characterized by the presence of five reentrant folds (Figure 58a; Russell and Harris, 1986). No extant North American leporid retains such a pattern and among fossil taxa, only *Nekrolagus* is similar (Russell and Harris, 1986). Specimens identified as *A. agilis* from Cathedral Cave all exhibit a strongly developed anterointernal fold and a well-developed anteroexternal fold (Figure 58b) or lake. The presence of a strongly developed anterointernal fold on the p3

distinguishes *A. agilis* from *Nekrolagus*, in which the fold is less developed or absent (Russell and Harris, 1986). The degree of crenulation within individual folds varies among individual specimens from Cathedral Cave. Table 16 summarizes the number of crenulations in the anteroexternal reentrant, along the posterior wall of the posterointernal reentrant, and along the posterior wall of the posteroexternal reentrant. Average length of the p3 was 2.40 mm (n = 25; SD = 0.23; range = 1.7-2.8) and average width was 2.29 mm (n = 25; SD = 0.34; range = 1.2-2.8) for specimens of *A. agilis* from Cathedral Cave. These average measurements are slightly larger than average measurements found by Winkler and Tomida (1988) for other localities in the southwestern United States.

Discussion-*Aztlanolagus* is known from Blancan to late Rancholabrean deposits in the western United States and Mexico. Records other than Cathedral Cave come from localities within Porcupine Cave, CO (Barnosky and Hopkins, 2004; Baxter, 2004), and localities in northern Mexico, New Mexico, Arizona, and Texas (Russell and Harris, 1986; Winkler and Tomida, 1988). Uncertainty in species diversity is reflected in the identifications from these localities. Specimens from Porcupine Cave were identified as *Aztlanolagus* sp. (Baxter, 2004) whereas Winkler and Tomida (1988) tentatively referred all specimens that they examined to *A. agilis*. I follow the latter approach. The taxonomic status of the genus *Aztlanolagus* is also uncertain, and may be formally synonymized with *Pliopentalagus*, an extinct leporid known from China (Tomida and Jin, 2004). Taxonomic issues notwithstanding, the disappearance of *A. agilis* is one of the few known late Quaternary small mammal extinctions in continental North America.

The records of *Aztlanolagus agilis* from Cathedral Cave presented here represent the first known occurrence of this extinct taxon in the Great Basin. An additional

unnumbered specimen of *A. agilis* was observed in bulk fossil samples from Smith Creek Cave, NV, housed at the Nevada State Museum (Jass, personal observation).

Brachylagus Miller, 1900

Brachylagus idahoensis (Merriam, 1891)

Referred Specimens-See Appendix 8.

Description-*Brachylagus* is distinguished from most extant and fossil North American leporids by the lack of an anterior reentrant on the p3 (Kurtén and Anderson, 1980; Ramos, 1999a). The extinct genus *Hypolagus* is similar in some qualitative aspects to an extinct form of *Brachylagus* (*B. coloradoensis*) but is larger in size (Ramos, 1999b). Until recently the genus *Brachylagus* was considered monotypic, with *B. idahoensis* as the only recognized species.

Three specimens of *B. idahoensis* were identified from Cathedral Cave (Figure 58c). Two of the specimens retain simple anteroexternal reentrants and the trigonid and talonid are completely separated by cementum (TMM 43693-1777) or nearly so (TMM 43693-1776). The extension of the anteroexternal folds across the tooth (or nearly so) is characteristic of *B. idahoensis* (Ramos, 1999b). Length and width of the p3s were: (TMM 43693-1777) - *l* = 1.8 mm, *w* = 1.6 mm; (43693-1776) - *l* = 1.8 mm, *w* = 1.8 mm.

A third specimen (TMM 43693-1775) with a damaged occlusal surface was identified as *B. idahoensis* although it is unique. In ventral view this specimen has a posteroexternal reentrant that extends across two-thirds of the tooth, but exhibits an enamel lake in the position of a posterointernal reentrant. Because the joining of the posteroexternal reentrant with the enamel lake would result in a morphology more similar

to *B. idahoensis* than *B. coloradoensis* (see below), I identified the specimen as the former. Further review of variation in the p3 enamel patterns of *B. idahoensis* is needed.

Discussion-Fossils of *B. idahoensis* are known only from the western United States and most fall within or near the present distribution of the species (Kurtén and Anderson, 1980). Exceptions are the records from Isleta Cave No. 2 and Sheep Camp Shelter in New Mexico (Harris, 1993). The occurrence of *B. idahoensis* at Cathedral Cave was previously noted by Ramos (1999b).

Brachylagus coloradoensis Ramos 1999

Referred Specimens-See Appendix 8.

Description-The two specimens identified as *B. coloradoensis* are similar to *B. idahoensis*, but both have a weakly developed posterointernal reentrant and a posteroexternal reentrant that extends only between one-third and two-thirds across the tooth (Figure 58c). As such, these specimens are consistent with specimens from Porcupine Cave, Colorado, that were designated as a new species named *B. coloradoensis* (Ramos, 1999b).

Discussion-Prior to this report *B. coloradoensis* was known only from several localities of either unknown or Irvingtonian-age within Porcupine Cave, Colorado (Ramos, 1999; Barnosky, 2004b; Barnosky and Hopkins, 2004; based on age assignments presented by Barnosky et al., 2004). The records of *B. coloradoensis* from Cathedral Cave extend both the geographic and chronologic ranges of the species.

Sylvilagus Gray 1867 or *Lepus* Linnaeus 1758

Sylvilagus or Lepus sp.

Referred Specimens-See Appendix 8.

Description-Specimens identified as *Sylvilagus* or *Lepus* sp. are characterized by the presence of three reentrant folds (anterior, anteroexternal, and posteroexternal) on the p3. The presence of the anterior fold distinguishes these specimens from *Ochotona*, which typically retains three reentrant folds on the p3. In most specimens the anterior and anteroexternal reentrants are simple with little crenulation. All specimens have a large posteroexternal reentrant fold that may or may not exhibit crenulations. Length and width of the p3s are listed in Appendix 8 and are plotted on a scatter plot used to evaluate if distinct size groupings exist (Figure 59).

Discussion-*Sylvilagus audubonii, S. nuttalli, Lepus californicus,* and *L. townsendii* all have modern ranges that include the region surrounding Cathedral Cave. One, all, or none of these taxa may be represented in Cathedral Cave. Previous authors noted that there is considerable difficulty in the identification of *Lepus* versus *Sylvilagus* (e.g., Kurtén and Anderson, 1980) and that size overlap occurs (Dalquest and Schultz, 1992; Ramos 1999). Because it would be necessary to invoke either geographic or evolutionary assumptions (i.e., constant size in the past relative to the modern) to separate these genera, I did not attempt to differentiate *Lepus* and *Sylvilagus* from Cathedral Cave (see further discussion below).

DISCUSSION

An early report on lagomorphs from Cathedral Cave included *Ochotona princeps*, *Brachylagus idahoensis* (as *Sylvilagus idahoensis*), *Sylvilagus* sp., and *Lepus* sp. (Bell, 1990). The results of the 2003 excavation resulted in the recognition of a more diverse lagomorph assemblage that includes new records of *Brachylagus coloradoensis* and

Aztlanolagus agilis. The record of *A. agilis* is particularly notable because it consists of a reasonable sample size (n = 25) that might be used to further evaluate the variation in crenulation patterns of this taxon. Older specimens of *A. agilis* appear to have less complex crenulation patterns with respect to more recent specimens (Winkler and Tomida, 1988). My attempt to quantitatively evaluate crenulation patterns of the p3 in *A. agilis* from Cathedral Cave does not appear to show a pattern of increasing complexity (Table 16). This finding does not negate the possibility of such a pattern over a broader time scale, but does provide a quantitative measure by which specimens from other localities might be compared. Nevertheless, the occurrence of *A. agilis* at Cathedral Cave provides an important record for understanding Pleistocene-Holocene lagomorph diversity in the Great Basin and western North America.

Fossil lagomorphs have had a prominent role in paleontological research in the Great Basin since the 1970s when Brown (1971, 1978) published his classic research on montane mammal biogeography. Those studies helped initiate a number of research projects on Great Basin lagomorphs (e.g., Grayson, 1977; Mead, 1987; Hafner, 1993; Mead and Spaulding, 1995), and continue to influence research on lagomorphs of the region (e.g., Grayson, 2005). The ubiquity of lagomorph fossils in the Great Basin makes them ideal for such studies because they are common constituents of many Pleistocene and Holocene vertebrate assemblages (e.g., Heaton, 1985).

Because one of my objectives was to include the lagomorph fossils from Cathedral Cave in a biogeographic analysis of the fauna (see Chapter 7), I took a more conservative approach to the identification of lagomorph taxa than all prior studies concerning lagomorphs in the Great Basin. This was necessary because I wanted to

identify taxa on the basis of morphological criteria that were as free of as many biogeographic and evolutionary assumptions as possible. The use of biogeographic data to limit possible identifications only to taxa currently inhabiting the Great Basin (e.g., *Sylvilagus audubonii, S. nuttalli, Lepus californicus,* and *L. townsendii*), or occurring in close proximity to it, would contribute to circularity in any subsequent biogeographic interpretation for the region.

Similarly, the invocation of size alone as a criterion for distinguishing species or genera (e.g., *Lepus* vs. *Sylvilagus*) assumes a pattern of stasis in body size relative to the modern, where such an assumption may not be appropriate. For example, it is possible that certain species of *Sylvilagus* were larger 130,000 years ago and more comparable in size to extant *Lepus*. In the absence of other independent characters, the size of a particular taxon might simply reflect ecophenotypic variation.

My conservative approach to identification is not intended as a criticism of the results of previous biogeographic or morphologic studies that include lagomorph fossils identified to lower taxonomic levels. Rather, my purpose is to provide baseline data that minimize the amount of inherent bias included at the outset of similar studies in the future. This approach should help determine whether previously observed patterns of biogeographic change or species replacement in the Great Basin may be supported at less refined taxonomic levels.

CONCLUSIONS

Cathedral Cave contains a diverse record of lagomorphs that includes *Ochotona* sp., *Aztlanolagus agilis*, *Brachylagus coloradoensis*, *B. idahoensis*, and *Sylvilagus* or

Lepus sp. The geographic ranges of *Aztlanolagus agilis* and *Brachylagus coloradoensis* are extended by virtue of their presence at Cathedral Cave, and the known chronologic range of *B. coloradoensis* is extended upwards to between 136 ± 23 kya and 153.7 ± 6.4 kya. The records of taxa presented here represent a conservative approach to identification that minimizes geographic and evolutionary assumptions. Future studies may determine how this conservative approach influences our understanding of the natural history of Great Basin mammals.

Table 16. Variation in the number of major crenulations on the anteroexternal reentrant (AER), posterior wall of the posterointernal reentrant (PW-PIR), and posterior wall of the posteroexternal reentrant (PW-PER) in the p3 of *Aztlanolagus agilis* from Cathedral Cave, Nevada, by excavated level. (?) = minimum number of crenulations. Dash (-) = data could not be evaluated. Specimen No. = unique specimen number for locality TMM 43693 (i.e., TMM 43693-1748 is the full number for the first specimen listed below).

Specimen No.	Excavated Level	AER	PW-PIR	PW-PER
1748	2N 3E 40-45 cmbd	0	1	0
1749	2N 3E 40-45 cmbd	0	2(?)	0
1750	1N 3E Cemented Level	2	4	2
1751	1N 3E 43.5-55 cmbd; below Cemented Level	-	2	2
1752	1N 3E 43.5-55 cmbd; below Cemented Level	0	4	3
1753	2N 2-3E 45-60 cmbd	0	2	2
1754	2N 2-3E 45-60 cmbd	-	-	-
1755	2N 2-3E 45-60 cmbd	0	2	2
1756	1N 2E 55-60 cmbd	-	2(?)	3
1757	1N 2E 60-65 cmbd	1	2	0
1758	2N 2-3E 60-65 cmbd	2	3	2
1759	2N 2-3E 60-65 cmbd	-	3	2
1760	1N 2E 65-70 cmbd	0	0	1
1761	1N 2E 65-70 cmbd	0	1	0
1486	1N 3E 65-70 cmbd	2	4	3
1762	2N 2-3E 65-70 cmbd	2	2	1
1763	2N 2-3E 65-70 cmbd	0	4	3
1764	2N 2-3E 70-75 cmbd	0	2	0
1765	2N 2-3E 70-75 cmbd	0	2	0
1766	1N 2-3E 75-80 cmbd	0	1	1
1767	2N 2-3E 75-80 cmbd	0	2	2
1768	2N 2-3E 80-85 cmbd	2	4	-
1769	1N 2-3E 85-90 cmbd	1	0	1
1770	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	1	1	1
1771	2N 2-3E 90-95 cmbd	1	2	1
1772	2N 2-3E 90-95 cmbd	1	0	1

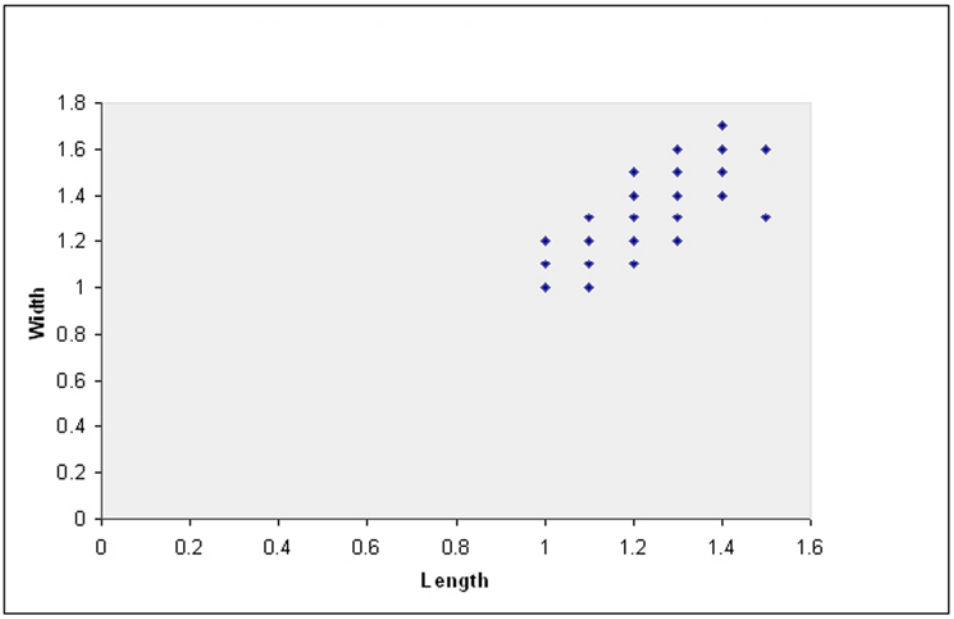


Figure 56. Scatter plot of length versus width in specimens of *Ochotona* sp. (n = 74) from Cathedral Cave, NV. Measurements were taken to nearest 0.1 mm using an ocular micrometer under a binocular microscope. See Appendix 8 for individual specimen data.

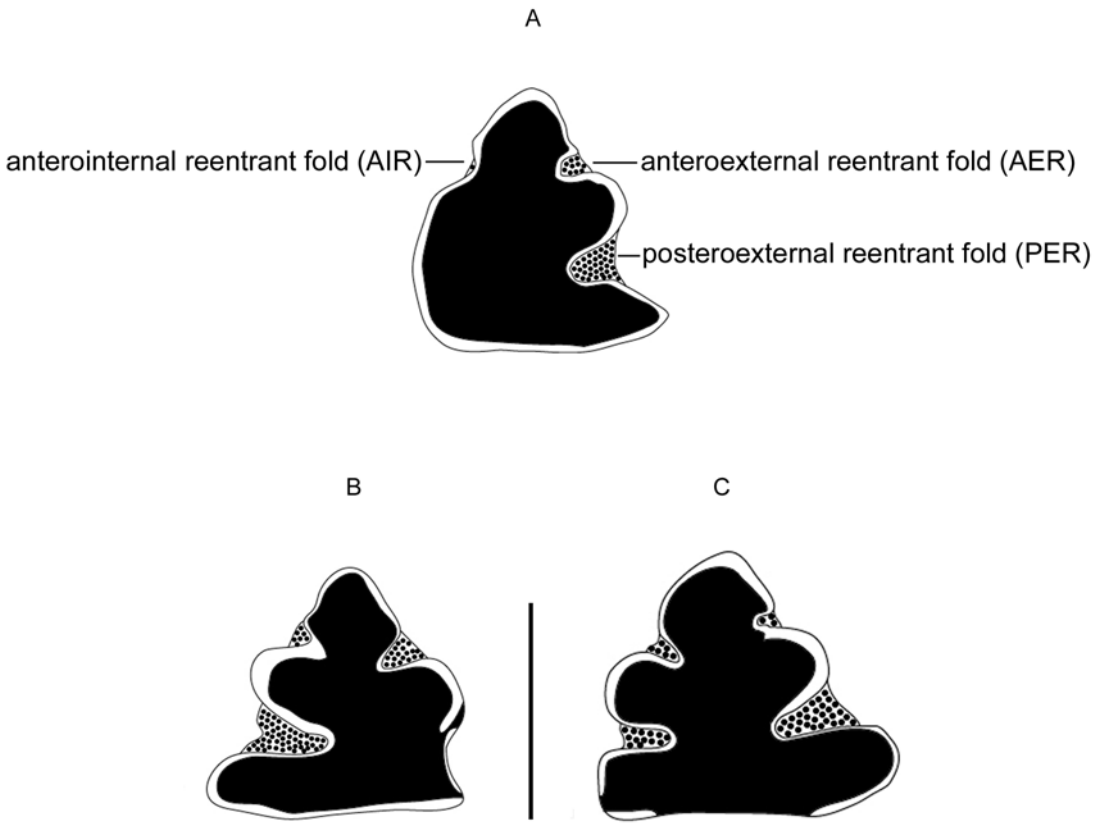


Figure 57. The p3 of *Ochotona* from Cathedral Cave. A. Generalized occlusal pattern and terminology discussed in text for the right p3 in *Ochotona*. B. Left p3 (TMM 43693-1814) of *Ochotona* sp. from Cathedral Cave. C. Right p3 of *Ochotona* sp. exhibiting a fourth reentrant fold (TMM 43693-1856). Scale bar = 1 mm.

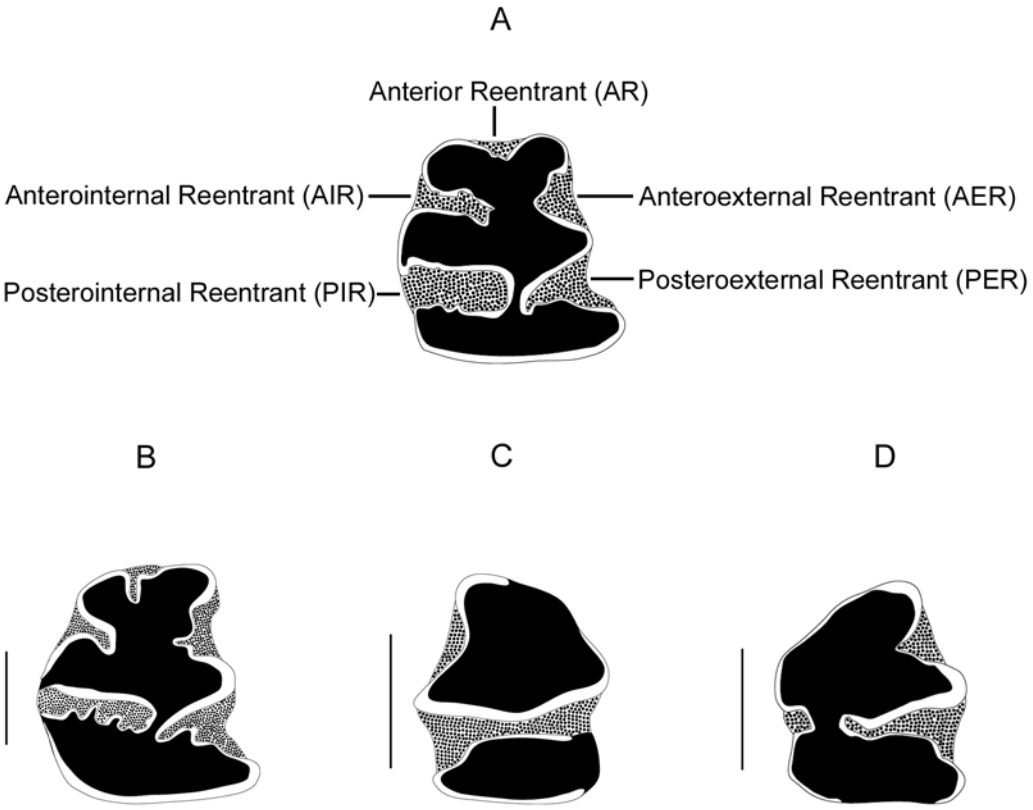


Figure 58. Leporid teeth from Cathedral Cave. A. General enamel pattern and terminology for the p3 in leporids. Terminology follows Baxter (2004). B. Left p3 of *Aztlanolagus agilis* (TMM 43693-1750) from Cathedral Cave. C. Left p3 of *Brachylagus idahoensis* (TMM 43693-1777) from Cathedral Cave. D. Right p3 of *Brachylagus coloradoensis* (TMM 43693-1774) from Cathedral Cave. Scale bars = 1 mm.

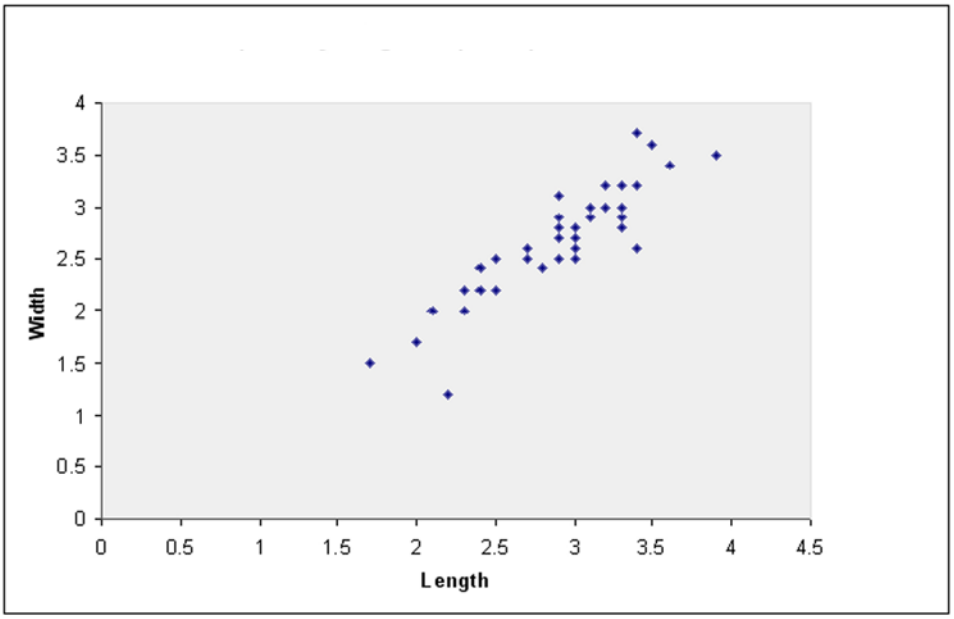


Figure 59. Scatter plot of length versus width in specimens identified as *Sylvilagus* or *Lepus* sp. (n = 42) from Cathedral Cave, NV.

CHAPTER 6: AN ALTERNATIVE PHILOSOPHICAL APPROACH TO THE IDENTIFICATION OF FOSSIL WOODRATS (*NEOTOMA*): AN EXAMPLE FROM CATHEDRAL CAVE, NEVADA

INTRODUCTION

Studies concerning fossil woodrats (or packrats; genus *Neotoma*) are an important part of the history of Quaternary research in North America (e.g., Betancourt et al., 1990; Grayson and Madsen, 2000). Significant time and energy were spent collecting, analyzing, and interpreting the contents of fossil woodrat middens, particularly in the arid west of North America (e.g., Wells and Jorgensen, 1964; Thompson and Mead, 1982; Betancourt et al., 1990; Coats, 1997). Midden studies have an important role in paleoecological interpretation (e.g., Betancourt 1990; Cole, 1990; Spaulding, 1990; Thompson, 1990; Van Devender, 1990a, b) and have also been used to evaluate the effects of livestock grazing on local vegetation (Cole et al. 1997). These studies often focus on the material components of the midden and are functionally treated as species-independent. Some studies do designate a particular species, or group of packrat species, as probable accumulators of individual middens on the basis of a variety of factors including fossil size, behavior, perceived modern ecological tolerances, or modern geographic distributions (e.g., Van Devender, 1990a). In many instances, a similar approach is taken in paleontological studies that focus on woodrat fossils themselves.

A combination of fossil size and location of fossils relative to the distribution of living packrat species is most commonly used as a basis for species identification of *Neotoma* in paleontological literature. In some studies this approach is explicitly stated

(e.g., Van Devender and Bradley, 1990; Smith and Betancourt, 1998), but in most the use of these criteria is implicit. As a result, our understanding of the paleontological history of woodrats is, in many instances, limited by differences seen among the extant fauna. While this approach may produce results that accurately portray past diversity of *Neotoma*, there is no independence from data on extant woodrats. Therefore, it is unlikely that we would ever be able to identify evolutionary, ecologic, or biogeographic changes in the fossil record of woodrats. In this paper, I review previous philosophical approaches to the identification of woodrat fossils and present an alternative approach using isolated specimens of *Neotoma* collected from Cathedral Cave, Nevada. Specifically, I evaluate a fossil data set from Cathedral Cave for the presence of multiple species of *Neotoma* using no *a priori* assumptions about the taxonomic character of the assemblage.

The Challenge of Woodrat Identification

Woodrats are known from the Miocene to Recent in North America (Zakrzewski, 1993). Across that span of time, the dentition of woodrats has remained relatively simple with a characteristic series of three confluent or offset lophs (Zakrzewski, 1993). In some lineages, the lower third molar (m3) has been reduced to a bilophate pattern (Zakrzewski, 1993). Other general trends include deepening of the reentrant folds and greater development of the dentine tract of the lower first molar (m1) in some taxa (Zakrzewski, 1993). Extinct *Neotoma* from the Irvingtonian and Rancholabrean land mammal ages were reported from localities in Arkansas (*N. ozarkensis*; Brown, 1908), Colorado (*N. ozarkensis*; Rogers et al., 1985), New Mexico (*N. findleyi* and *N. pygmaea*; Harris,

1984a), South Dakota (*N. amplidonta*; Zakrzewski, 1985b), and Mexico (*N. magnodonta*; Alvarez, 1966). A larger number of localities have fossils of *Neotoma* attributed to one of the extant species.

There are ten extant species of *Neotoma* recognized in the United States today and they inhabit a wide range of habitats (Wilson and Ruff, 1999). Geographically, they are found across much of the continental United States (excluding the Great Lakes and far northeast) and range as far north as 65º N latitude in northwestern Canada (*N. cinerea*) and as far south as Guatemala and Honduras (*N. mexicana*; Wilson and Ruff, 1999). They appear to have had a similarly broad geographic distribution throughout the Pleistocene (FAUNMAP Working Group, 1994). Glaciers likely effected the northernmost distribution in Canada during the Pleistocene, and the Pleistocene geographic distribution south of the United States is less well known. Of the ten extant species, seven have been reported from the fossil record (Kurtén and Anderson, 1980), suggesting that the species richness of woodrats in the United States during the Pleistocene was at least equal to that seen today.

The most comprehensive attempts to achieve species-level resolution for woodrat fossils from Quaternary deposits were primarily based on characters of the first lower molar (m1; e.g., Harris, 1984b; Force, 1990; Repenning, 2004). Lower first molars of *Neotoma* are common in the fossil record and are considered to have reasonable potential for species identification relative to other isolated elements (Harris, 1984b). Harris (1984b) evaluated a series of quantitative and qualitative features of the m1 for some modern and fossil *Neotoma*. Standard statistical techniques produced some species distinction, and secondary usage of discriminant function analysis provided further

separation (Harris, 1984b). Repenning (2004) evaluated qualitative characters of the m1, m2, and M1 for six extant taxa and for fossils from Porcupine Cave, Colorado. Species identifications for the fossils were based on character suites of the taxa considered in the study. Other criteria invoked for identification of *Neotoma* include characteristics of other teeth (Zakrzewski, 1985b; Hoffmeister and de la Torre, 1960), characteristics of the dentary (Harris, 1984b), and the size of fecal pellets (Smith and Betancourt, 1998).

All of the studies mentioned above are similar in the philosophical approach taken to species identification. All of them use data concerning extant woodrats as a starting point in the identification process (e.g., limiting potential identifications based on modern geographic distributions). While this is certainly a reasonable approach, I contend that overall there has been little progress made in identifying unique character differences among individual species of woodrats that are applicable over a broad time-scale. For instance, differences seen in the size of the m1 and dentine tract of extant species (e.g., *Neotoma lepida* versus *N. cinerea*) appear to have some utility for distinguishing groups of taxa and could used as a basis for excluding certain taxa from an analysis (Harris, 1984b). However, when applied to the fossil record, this approach assumes that those features have been fixed in their respective lineages throughout time and space. It assumes that *N. cinerea* has always had a larger dentine tract than *N. lepida*, a potentially problematic assumption given that older specimens of *Neotoma* lack a dentine tract (Zakrzewski, 1993).

A similar issue results when size alone is invoked as a primary character in the identification process. Although there are some documented size differences in the m1 of extant species (e.g., *N. cinerea* vs. *N. lepida*; Harris 1984b), the use of size as a

diagnostic character results from an assumption of stasis in body size. This is particularly problematic because studies on other rodent groups indicate that body size can reflect ecophenotypic response to climate change (Hadly, 1997). A study focused on size-change in woodrat pellets from the Colorado Plateau suggests that a similar type of response may occur in woodrats (Smith and Betancourt, 1998). However, whether the change noted by Smith and Betancourt (1998) can be attributed to a single species (*N. cinerea*) is dependant on geographic and ecologic assumptions made in the initial species identification.

Regardless of the criteria used to identify species of fossil woodrats, historically there has been a heavy dependence on our knowledge of modern woodrats in the identification process. The delineated boundaries (morphologic, geographic, or ecologic) for the extant species ultimately determined how fossil specimens were treated. As I began to work with isolated woodrat specimens from Cathedral Cave, I felt less and less confident about using such an approach to identification.

Why Take a Different Approach to Identification?

I want to specify that my intent is not to disparage the work of other researchers. In fact, I personally invoked identification methods similar to those outlined above in my previous work (e.g., Jass, 2000), and I think that in many instances the results derived from such identification methods are probably correct. However, my work at Cathedral Cave forced me to confront certain assumptions in the identification process of Quaternary mammal species, in part because the site contains a faunal component that

pre-dates the terminal Pleistocene. I am simply less confident that many of the features used to identify fossil woodrats, such as size, are phylogenetically informative when considered on a longer time-scale. Likewise, my confidence in making restricted geographic comparisons is lessened by the fact that I am dealing with older faunal components. Whereas certain assumptions seem reasonable at one time scale (e.g., late Holocene woodrats in the Great Basin are probably *N. lepida* or *N. cinerea*), those same assumptions may draw us further from the truth as we carry our investigations further back in time. That, coupled with the fact that I am interested in understanding biogeographic, morphologic, and ecologic change at Cathedral Cave, required that my identifications be independent of as many assumptions about biogeography, morphology, and ecology as possible. In essence, my evaluation of other methods of *Neotoma* species identification represents the evolution in my personal thinking about the identification of woodrats from Cathedral Cave.

MATERIALS AND METHODS

Woodrat fossils were collected from Cathedral Cave, Nevada, as part of a systematic excavation undertaken in June, 2003. The excavation was conducted by hand and most sediments were removed in arbitrary, 5-cm levels. Excavated sediments were dry-screened, and later washed through paired box screens (0.7 mm and 3.18 mm mesh). All matrix from coarser screens was sorted for fossils. Sorted matrix from the fine screens consisted of a single bag from each unique level. More detailed descriptions of the excavation and sampling methods were presented in Chapter 1.

The age of the excavated materials was evaluated using biochronologic, paleomagnetic, and radioisotopic data. Radioisotopic data indicate an age between 146.02±2.584 ka to 151.2±4.4 ka for lower portions of the excavated sequence. Although no specific ages are known for overlying sediments, the homogeneity of the fauna suggests that much of the excavated sequence is similar in age, and likely predates the terminal Pleistocene (see Chapter 3).

All isolated m1s, and dentaries retaining the m1, were sorted into individual vials. Other teeth were sorted from matrix as batch samples but were not included in this study. I focused on the m1s because they appear to have the greatest potential for species identification. A total of 1806 m1s were evaluated in this study (Appendix 9).

Where preservation permitted (n = 856), occlusal width of the second loph of the m1 and dentine tract height were measured (Fig. 60a; Appendix 9). I focused on these measurements because they were similar to measurements used to produce scatter plots that previously showed differences in extant taxa (Fig. 60b; Harris, 1984b). I also took measurements of occlusal length, even though other researchers pointed out that this feature varies significantly with wear (Harris, 1984b). Future data collection from the Cathedral Cave woodrat fossils may allow for a quantifiable measure of how this feature varies with wear. An attempt to take measurements of the anterobuccal and posterobuccal reentrants, a character qualitatively evaluated by Repenning (2004), was unsuccessful because of my inability to identify consistent reference points from which measurements could be taken. All measurements were taken to the nearest 0.05 mm using an ocular micrometer.

Lower first molar width versus dentine tract height was plotted for each specimen in an attempt to identify unique data clusters that might represent individual species. Additionally, the distribution of dentine tract heights was plotted on histograms because differences in this character often are noted in species-level identifications (e.g., Repenning, 2004). Thus, if scatter plots or histograms resulting from the Cathedral Cave material showed distinct patterns of clustering within a specified sedimentary level, I might hypothesize that multiple species were present in that level. While this is a similar methodological approach to that which others have taken to fossil woodrat identification (i.e., Harris, 1984b), I suggest that it is philosophically quite different (see discussion).

RESULTS

Figures 61-74 show graphs of the width of the m1 versus dentine tract height by excavated level. Figure 75 is a summary graph for all excavated levels. None of the graphs show clear clustering that I would interpret as indicating species boundaries. Some outliers are present (e.g., Fig. 68), but no distinct separation or major clusters are evident.

Figures 76-89 are histograms depicting the number of specimens of a given dentine tract height by excavated level. Figure 90 is a summary histogram for all excavated levels. Among the data for individual levels, there are instances where a polymodal distribution might be interpreted (e.g., Figs. 81-86). In these instances the presence of more than one species could be hypothesized on the basis of higher versus lower dentine tracts. However, the overall patterns of the histograms are not clearly

different from level to level, particularly those with larger samples sizes (i.e., Figs. 81-86). If multiple species are present in the deposit, they were probably present throughout the period of fossil deposition at Cathedral Cave. Average dentine tract height values through the excavated sequence further support this interpretation (Table 17). Slight changes in average dentine tract height occur from level to level, but not to a degree that exceeds two standard deviations (Table 17), indicating little variation through time.

DISCUSSION

Given the possibility that more than one species of woodrat may be present in the Cathedral Cave assemblage, a series of questions must be considered. First, can the fossils possibly be attributed to any particular species on morphological grounds? Given the known ranges of m1 width and dentine tract height in extant *Neotoma,* reliable species assignments are not possible. Harris (1984b) provided ranges in these characters for several species of *Neotoma* and many of the Cathedral Cave specimens fall within ranges of more than one taxon. Certainly, there are some specimens that are consistent with a single taxon, (e.g., *N. cinerea*) but that assignment assumes that no other species of *Neotoma* was ever as large as *N. cinerea*. Furthermore, it assumes that the variation in specimens from the Southwest that was reported by Harris (1984b) is geographically applicable to specimens from the Great Basin. Even if comparable data were available for the Great Basin that allowed for clear division of the extant species occurring in the region today (*N. cinerea* and *N. lepida*), the morphologic characterstics of the woodrat specimens would not exclusively support identification to one of the extant taxa.

A second question I ask is what information would be gained by assigning the fossils to a particular species? I must concede that I think that the specimens from Cathedral Cave probably represent *N. cinerea* and *N. lepida*, the two species occurring in the region today (Hall, 1946). Morphologically and geographically, these identifications make sense, but what I think is not as important as what I can demonstrate and support with data. The fact that average m1 size and dentine tract height remain stable through the excavated sequence suggests that little information relevant to the current study would be gained by assigning the fossils to *N. cinerea* or *N. lepida*. If there had been significant changes in those averages through time, an argument for species or abundance changes might be made. Because that is not the case, there is little gained by invoking modern geographic distributions to refine species names applied to the Cathedral Cave woodrats. Without independent evidence (e.g., morphological, DNA) to support species-level identifications, assigning the fossils to *N. lepida* or *N. cinerea* would create more significant problems by introducing that data into public realm where it might be utilized for broad geographic (e.g., FAUNMAP), ecologic (e.g., paleoecologic reconstruction based on modern habitat tolerances), or evolutionary analyses (e.g., phylogenetic analyses).

The question then becomes, what would be disadvantageous about assigning species names to the Cathedral Cave woodrat fossils? Assigning the woodrats to a particular species would mean identifying the fossils at a taxonomic level beyond which the morphologic data currently permit. The morphologic data collected for this study simply do not permit identification beyond *Neotoma* sp. Invoking other criteria, such as geography or time, to refine the identification further would be a potential impediment to

subsequent research. Because primary paleontological data (i.e., identifications) are necessarily used in secondary analyses (e.g., anchors for molecular divergence times, broad-scale paleobiogeographic analyses), it is important that the criteria used for identification be independent of as many geographic and temporal assumptions as possible. At the least, the degree to which geographic and temporal data were used in the identification process should be made clear so that future researchers may evaluate the appropriateness of inclusion of these primary data in secondary analyses.

The results of my study do not necessarily mean that *Neotoma* fossils cannot be identified at the species level. Rather, for this particular analysis, the morphologic data used to evaluate the fossils do not support species-level identification. The methods used to identify possible species differences were simply insufficient to do so.

Nevertheless, a consistent statistical pattern in size and dentine tract height of *Neotoma* was recorded through excavated levels from Cathedral Cave. This supports an interpretation that the population of woodrats occurring in and around Cathedral Cave was stable during the period of fossil deposition. No evidence of faunal replacement in woodrats was detected. This final point is particularly important, because it indicates that even if species names were applied, the only thing that would be achieved is a false sense of taxonomic resolution. The interpretation of faunal change, or stability in the case of Cathedral Cave woodrats, is unaffected by an identification of *Neotoma* sp.

The approach to identification taken in this study will likely be deemed quite conservative. Philosophically, it is quite a different approach to woodrat identification than I, and others, have taken in the past (e.g., Harris, 1984b; Jass, 2000). Evaluating possible differences in the woodrat fossils first, and not limiting the identification process

a priori through geographic or temporal assumptions achieves a more independent level of identification. In other words, the woodrat fossils are identified at an appropriate taxonomic level for inclusion in secondary studies of broad biogeographic or evolutionary change.

Future research may show that there are species-diagnostic characters preserved in the m1 of *Neotoma*. Certainly, new computer-based morphometric programs may improve our ability to obtain additional measurements. There are indications that the enamel microstructure of teeth in some rodent groups is species-diagnostic (Wallace, 1999). Additional research could also be conducted to examine tooth wear in *Neotoma* in order to conduct morphometric analyses on individual teeth of known maturity. Other potential research trajectories include the examination of other skeletal elements for species-diagnostic characters and DNA analysis of fossil specimens.

CONCLUSIONS

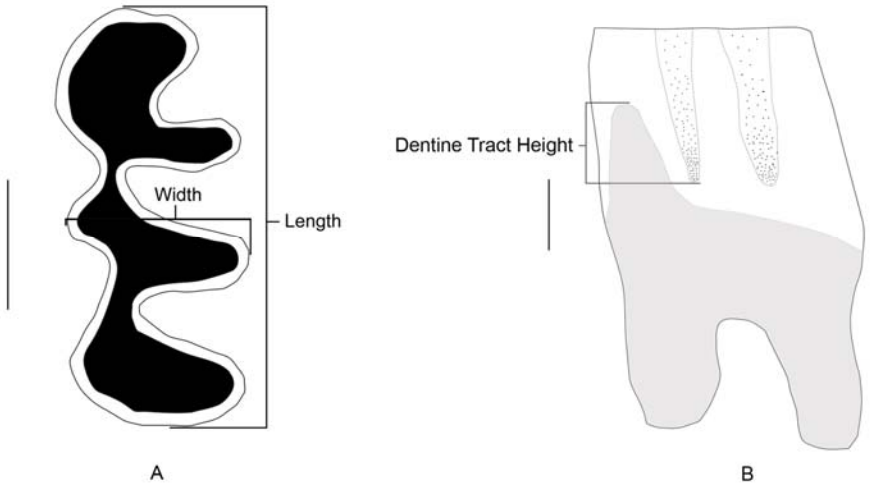
Isolated teeth of woodrats are common components of Quaternary deposits in North America. The observed range of variation in morphology, ecologic tolerances, and geographic distribution of extant woodrats traditionally formed the basis for recognition of species in the Quaternary fossil record. The use of a different philosophical approach, with no *a priori* morphologic, ecologic, or geographic assumptions about the taxonomic character of the assemblage, was undertaken in an attempt to identify the presence or absence of multiple species of fossil woodrats from Cathedral Cave, Nevada. Morphologic data and basic statistical analyses indicate that all woodrat specimens from

Cathedral Cave are most appropriately identified as *Neotoma* sp. Although this approach is conservative, it results in a data set that may be appropriately included in secondary analyses of evolutionary or biogeographic change. There appears to have been a stable population of *Neotoma* in and around Cathedral Cave from between 90-182 ka to the end of deposition at the site.

Table 17. Mean values for occlusal length (l), occlusal width of the second loph of the m1 (w), and dentine tract height (dth) for specimens of *Neotoma* from Cathedral Cave by excavated level. Range is given in parentheses. SD= standard deviation. N = number of specimens. The total N (765) presented in this table differs from the total number of specimens measured. Specimens that could not be assigned to one of the excavation levels listed below were excluded (e.g., no provenience specimens).

Level	Mean l	SD	Mean w	SD	Mean dth	SD	N
25-30 cmbd	(2.90-3.30) 3.17	0.23	(1.40-1.60) 1.50	0.10	(0.60-1.55) 1.02	0.49	3
30-35 cmbd	(2.95-3.80) 3.24	0.27	(1.35-1.80) 1.59	0.17	(0.30-1.50) 0.82	0.47	8
35-40 cmbd	(2.90-3.70) 3.23	0.21	(1.30-1.80) 1.57	0.14	(0.45-2.00) 1.15	0.48	13
40-45 cmbd	(2.70-3.75) 3.23	0.28	(1.35-1.90) 1.60	0.14	(0.30-2.00) 1.01	0.49	37
Cemented Level	(2.50-3.85) 3.30	0.31	(1.30-2.00) 1.64	0.17	(0.00-2.10) 1.03	0.51	41
45-60 cmbd	(2.40-3.90) 3.23	0.31	(1.20-2.05) 1.59	0.17	(0.00-2.25) 0.97	0.50	203
60-65 cmbd	(2.60-3.90) 3.24	0.31	(1.25-1.85) 1.60	0.15	(0.00-2.10) 0.93	0.40	91
65-70 cmbd	(2.65-3.75) 3.24	0.29	(1.25-2.95) 1.63	0.22	(0.15-2.60) 0.96	0.48	77
70-75 cmbd	(2.50-3.90) 3.24	0.31	(1.20-2.05) 1.62	0.17	(0.10-2.10) 0.89	0.43	116
75-80 cmbd	(2.70-3.90) 3.31	0.28	(1.30-2.00) 1.67	0.16	(0.10-1.95) 0.89	0.39	81
80-85 cmbd	(2.65-4.10) 3.22	0.30	(1.30-2.00) 1.64	0.16	(0.20-1.70) 0.84	0.37	60
85-90 cmbd	(2.80-3.65) 3.20	0.27	(1.45-1.90) 1.61	0.12	(0.15-1.95) 0.85	0.50	15
90-95 cmbd	(2.80-3.75) 3.19	0.37	(1.40-1.90) 1.60	0.17	(0.15-1.60) 0.74	0.54	8
95 cmbd and below	(2.80-3.70) 3.16	0.31	(1.35-1.80) 1.55	0.13	(0.35-1.40) 0.86	0.31	12

A.



B.

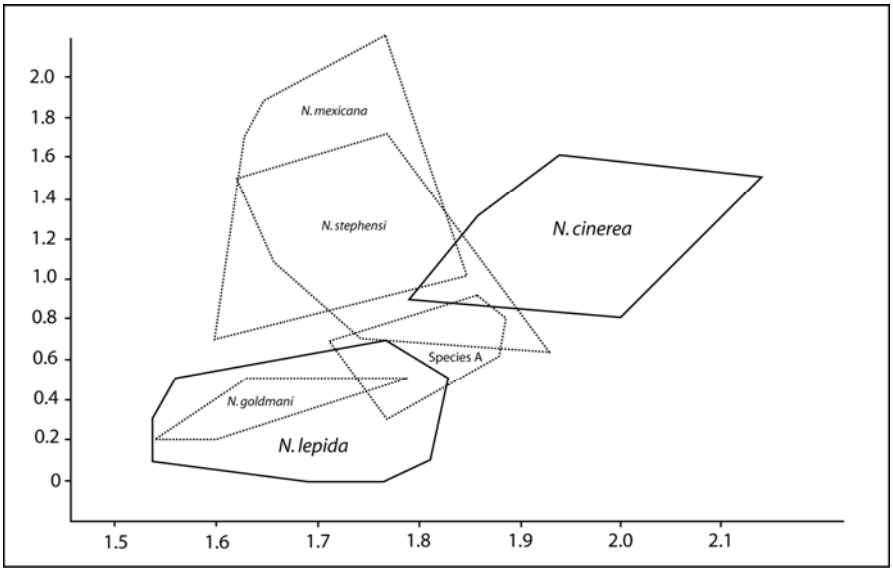


Figure 60. The lower m1 of *Neotoma* and graphic representation of width versus tract height data. A. Measurements taken in this study. a. Occlusal length and width of the second loph of the m1. b. Dentine tract height. B. Scatter plot from Harris (1984b) showing separation of species of *Neotoma* based on width of m1 (x-axis) versus dentine tract height (y-axis).

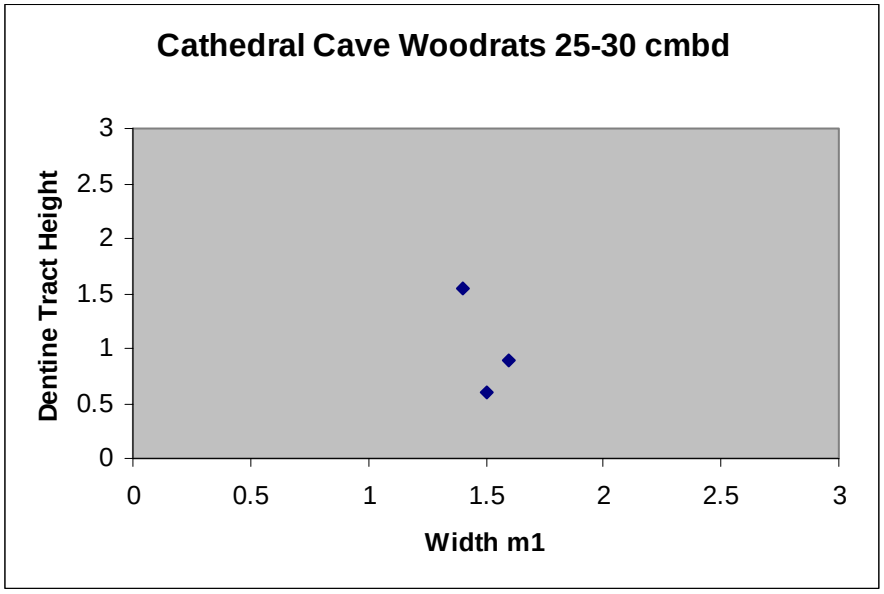


Figure 61. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 25-30 cmbd in Cathedral Cave; n = 3.

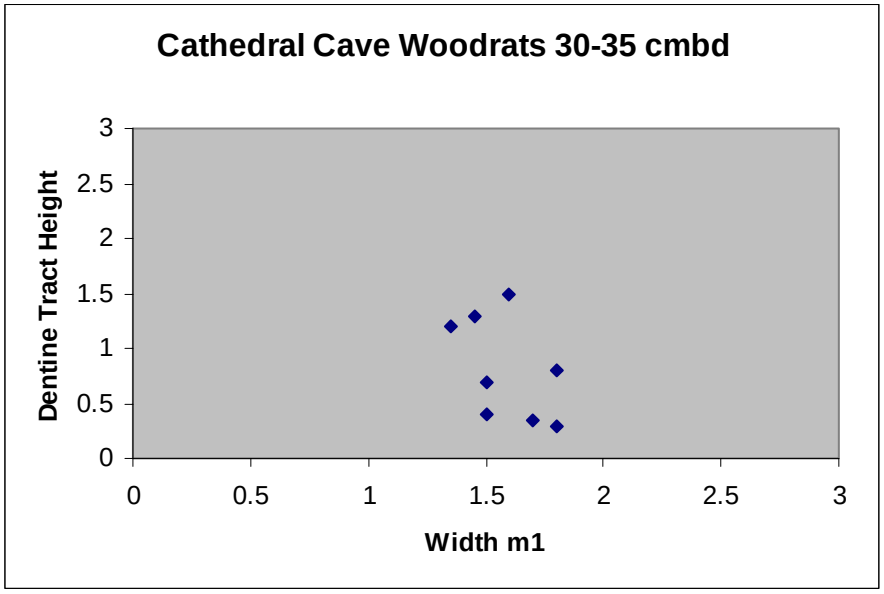


Figure 62. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 30-35 cmbd in Cathedral Cave; n = 8.

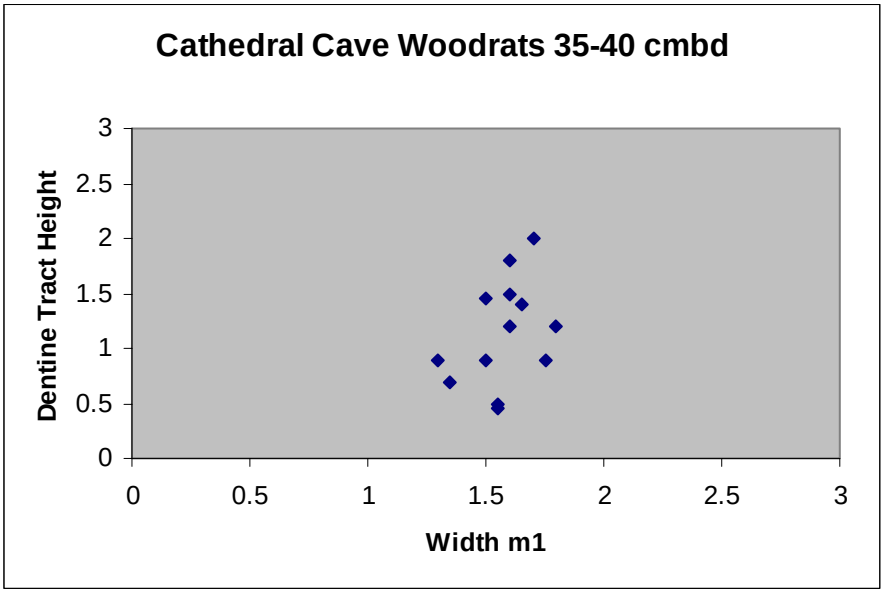


Figure 63. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 35-40 cmbd in Cathedral Cave; n = 13.

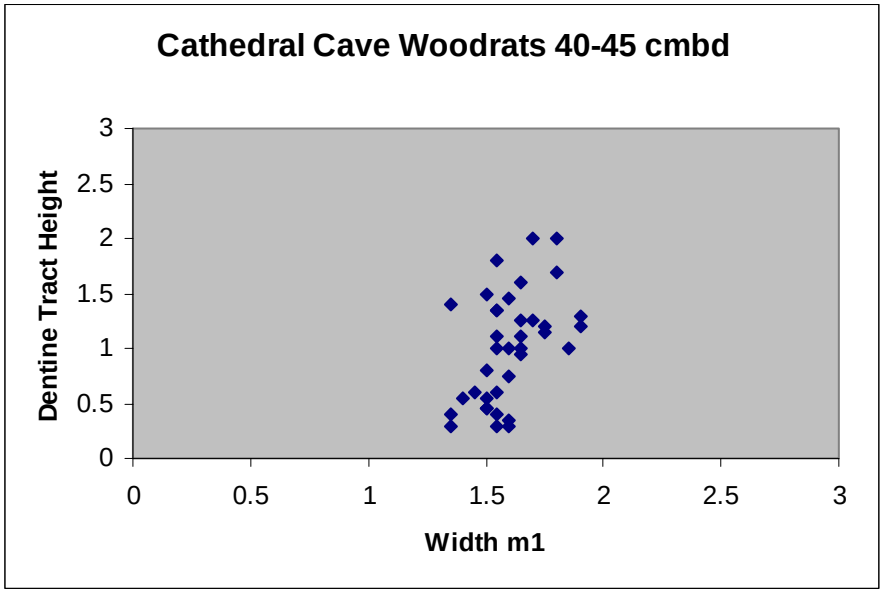


Figure 64. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 40-45 cmbd in Cathedral Cave; n = 37.

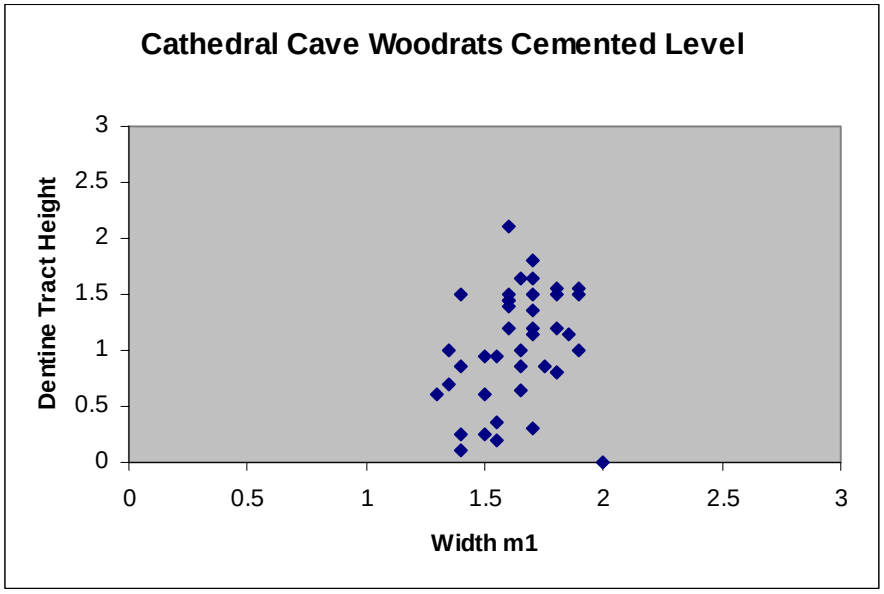


Figure 65. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from the cemented level in Cathedral Cave; n = 41.

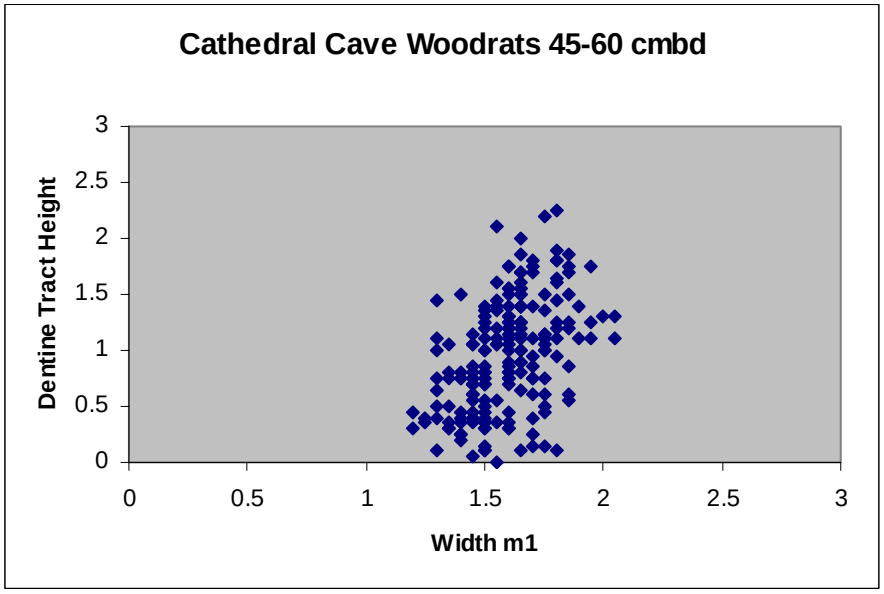


Figure 66. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 45-60 cmbd in Cathedral Cave; n = 203.

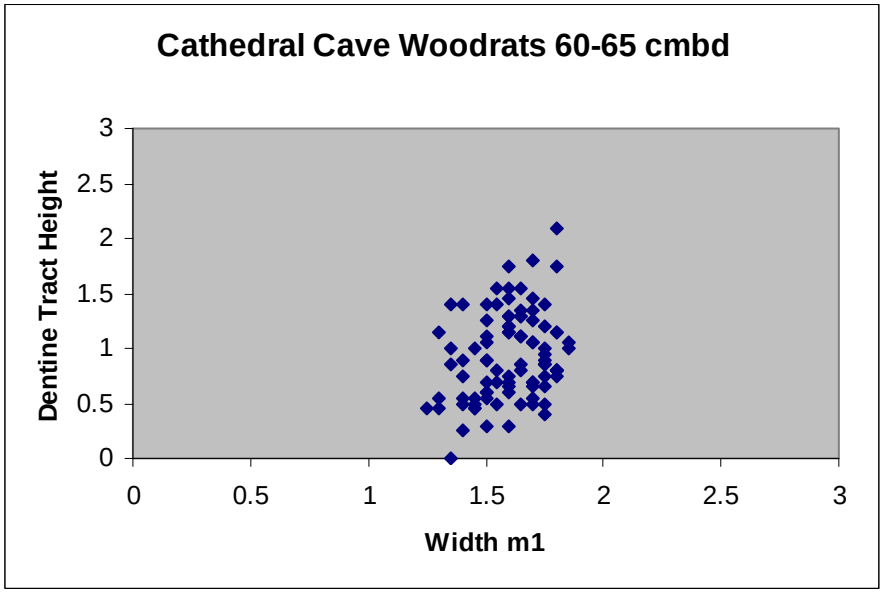


Figure 67. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 60-65 cmbd in Cathedral Cave; n = 91.

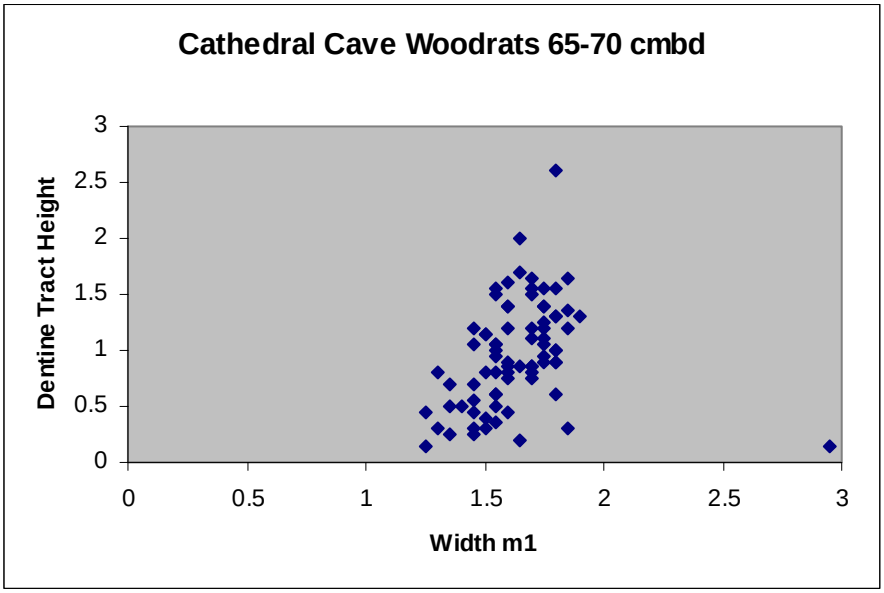


Figure 68. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 65-70 cmbd in Cathedral Cave; n = 77.

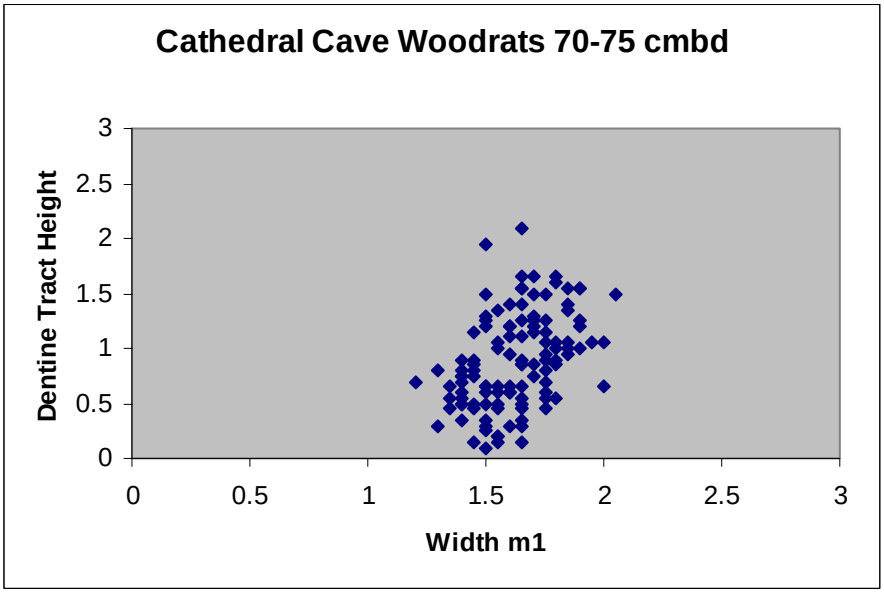


Figure 69. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 70-75 cmbd in Cathedral Cave; n = 116.

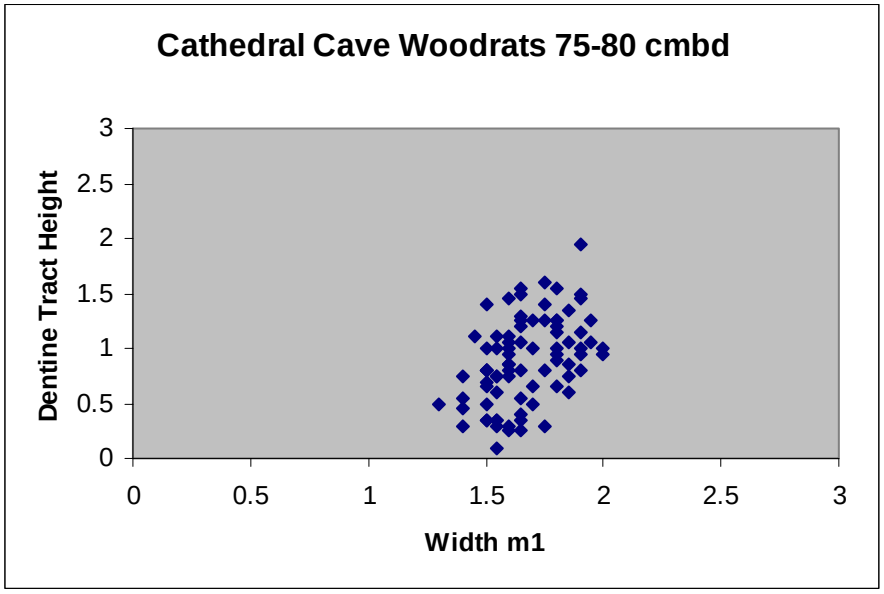


Figure 70. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 75-80 cmbd in Cathedral Cave; n = 81.

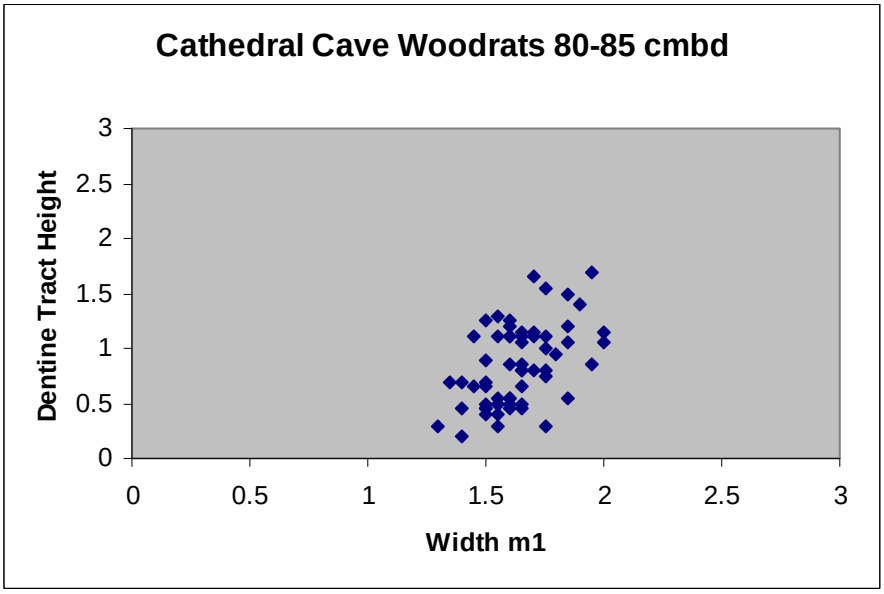


Figure 71. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 80-85 cmbd in Cathedral Cave; n = 60.

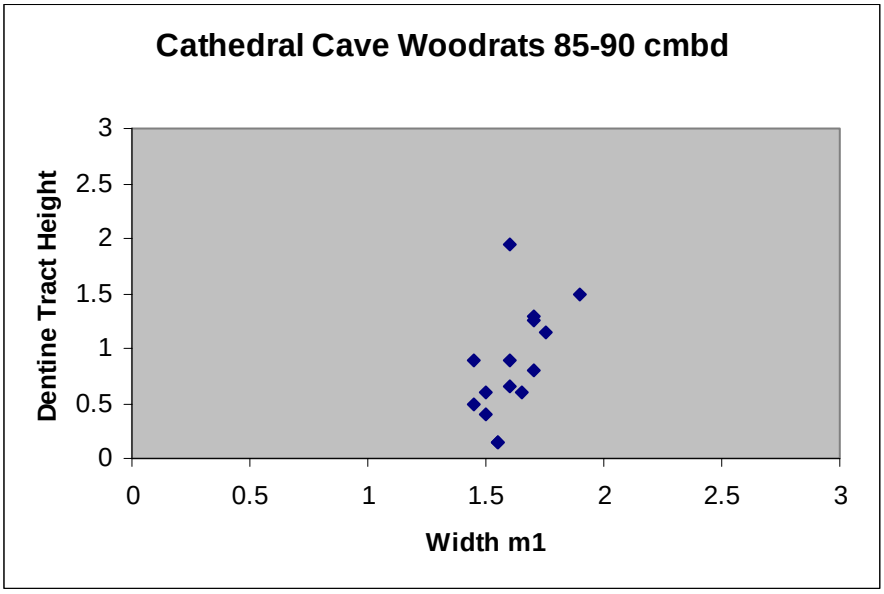


Figure 72. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 85-90 cmbd in Cathedral Cave; n = 15.

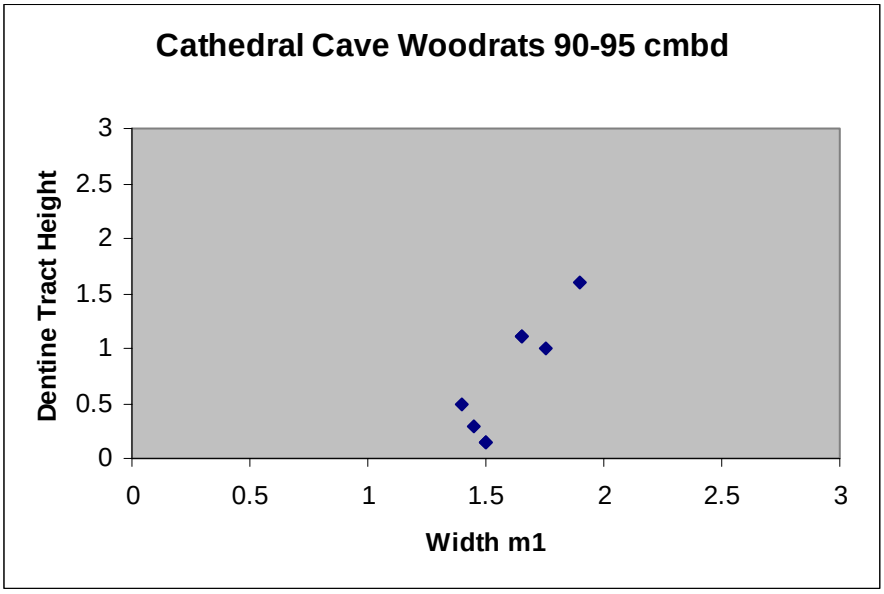


Figure 73. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 90-95 cmbd in Cathedral Cave; n = 8.

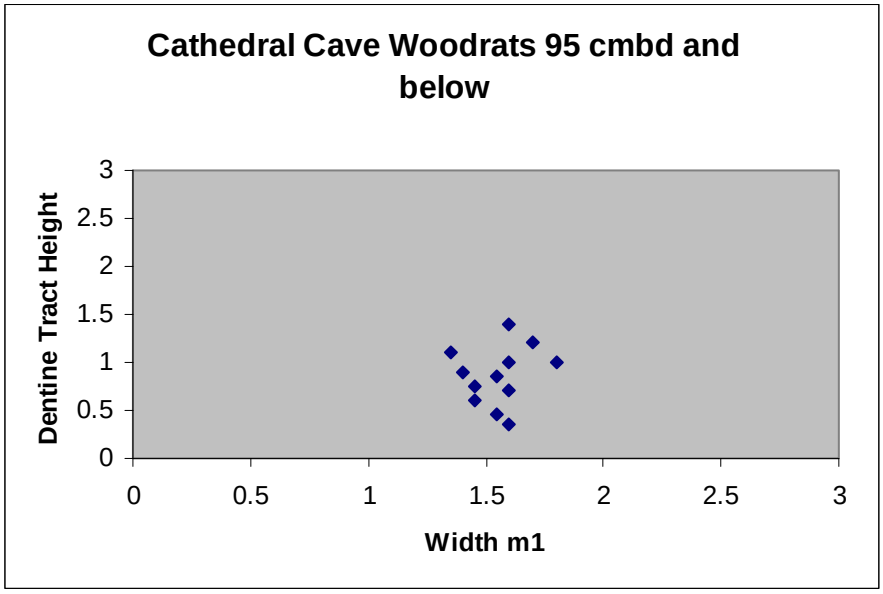


Figure 74. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from 95 cmbd and below in Cathedral Cave; n = 12.

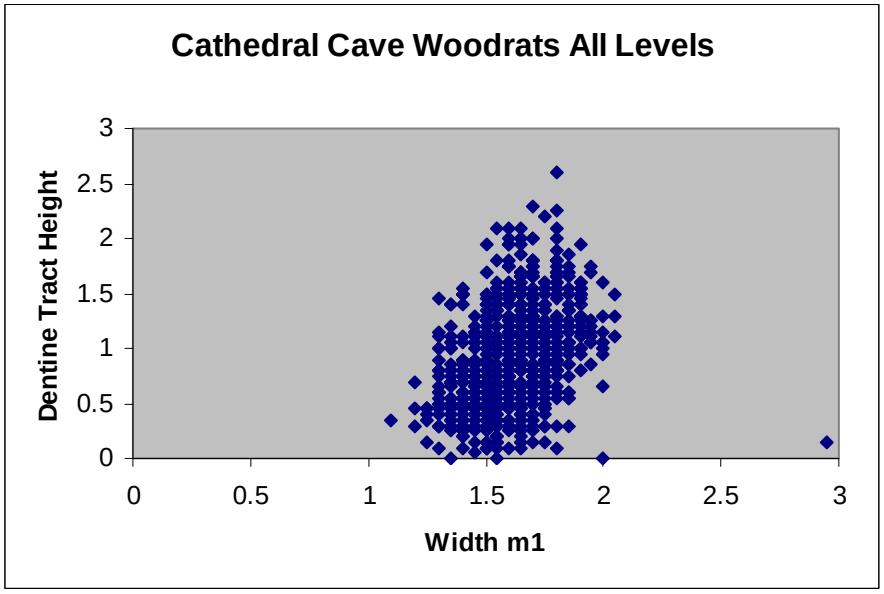


Figure 75. Scatterplot of width of the m1 versus dentine tract height in woodrats collected from all levels in Cathedral Cave; n = 856.

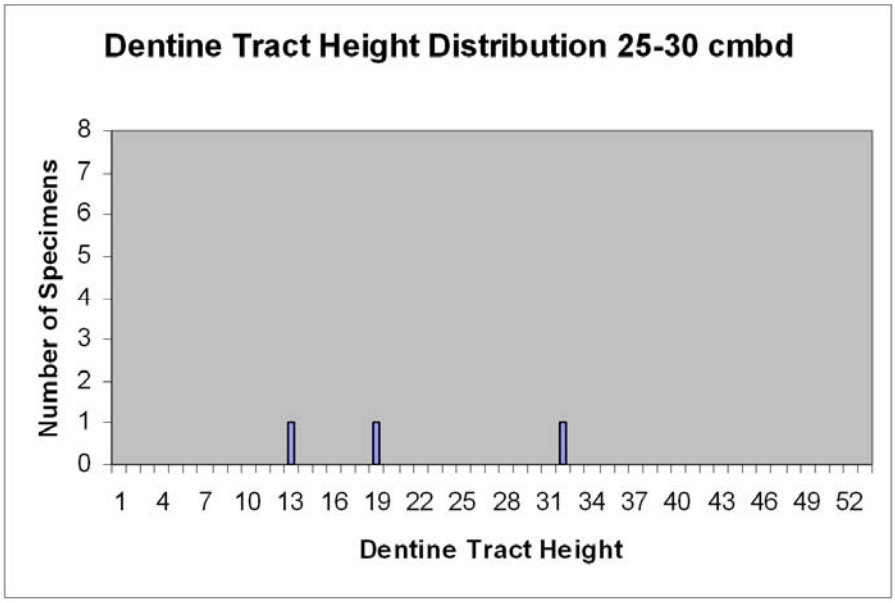


Figure 76. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 25-30 cmbd; n = 3.

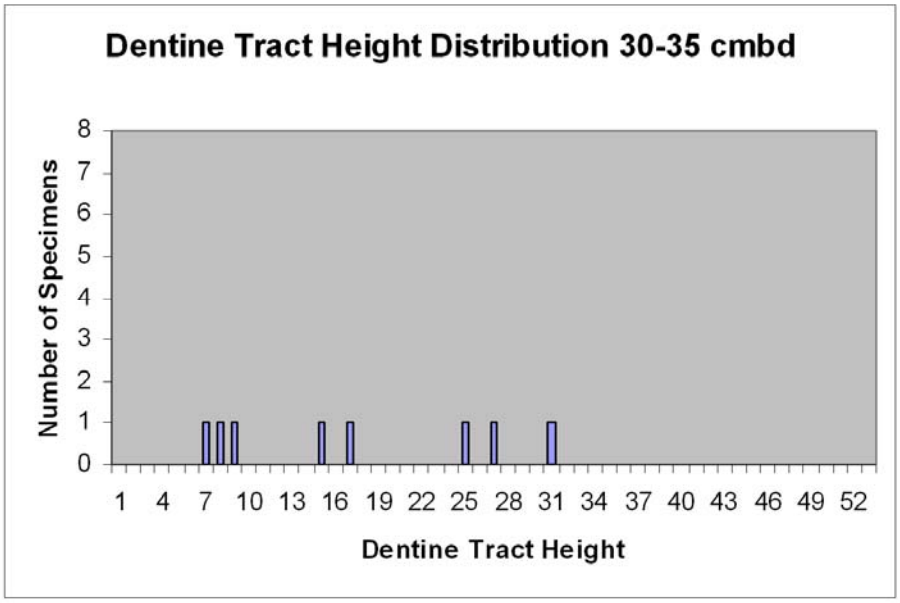


Figure 77. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 30-35 cmbd; n = 8.

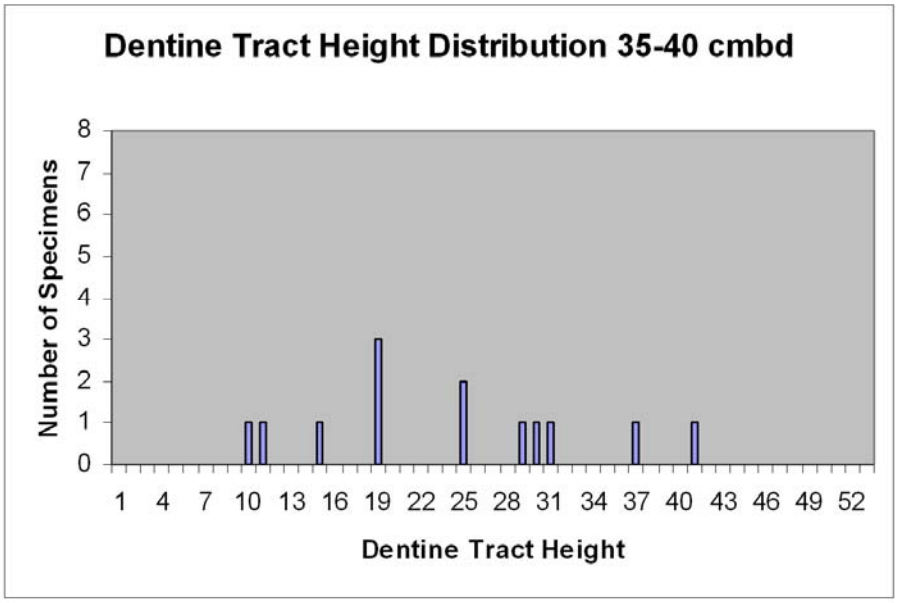


Figure 78. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 35-40 cmbd; n = 13.

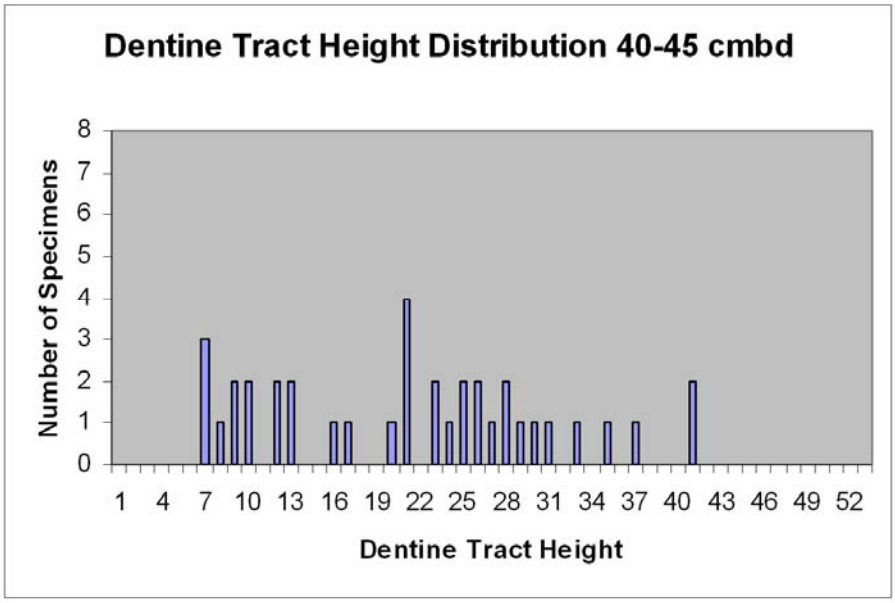


Figure 79. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 40-45 cmbd; n = 37.

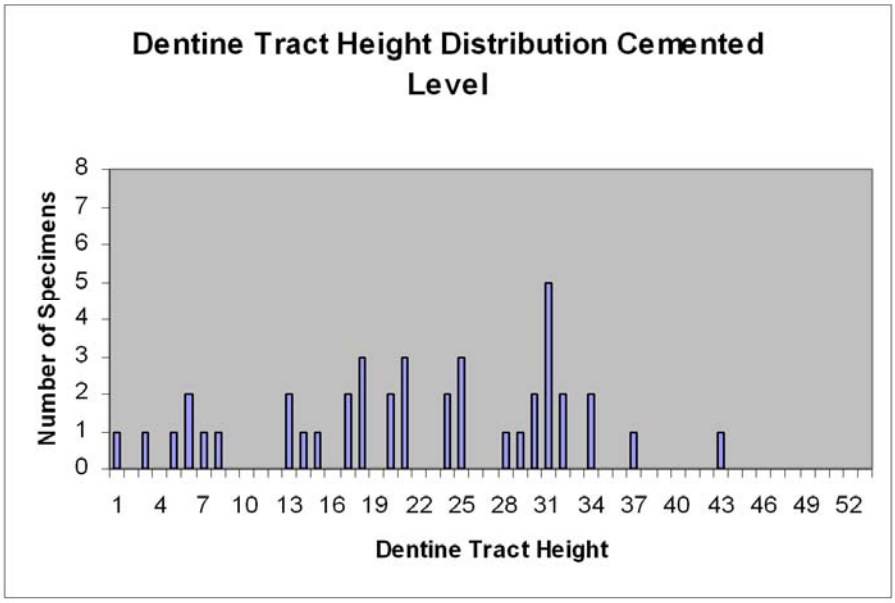


Figure 80. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for cemented level; n = 41.

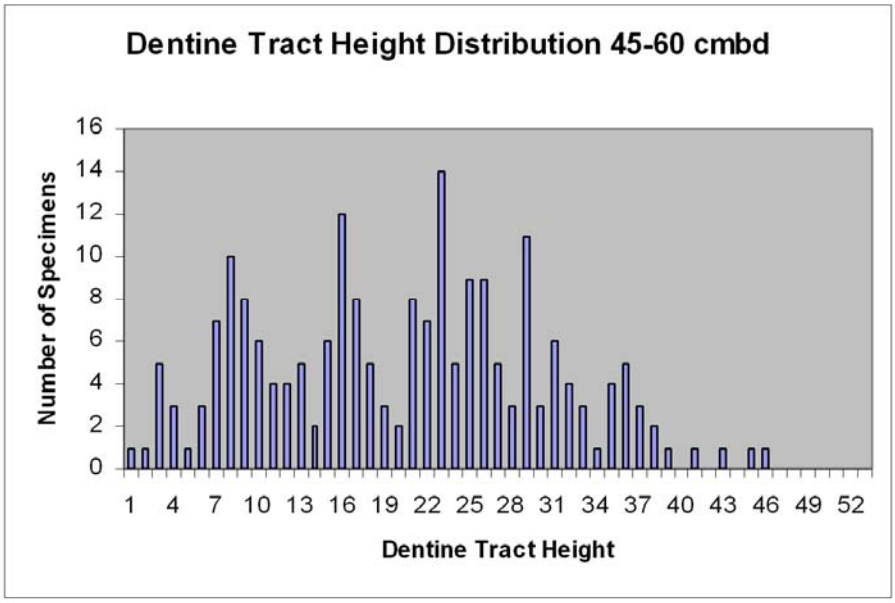


Figure 81. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 45-60 cmbd; n = 203.

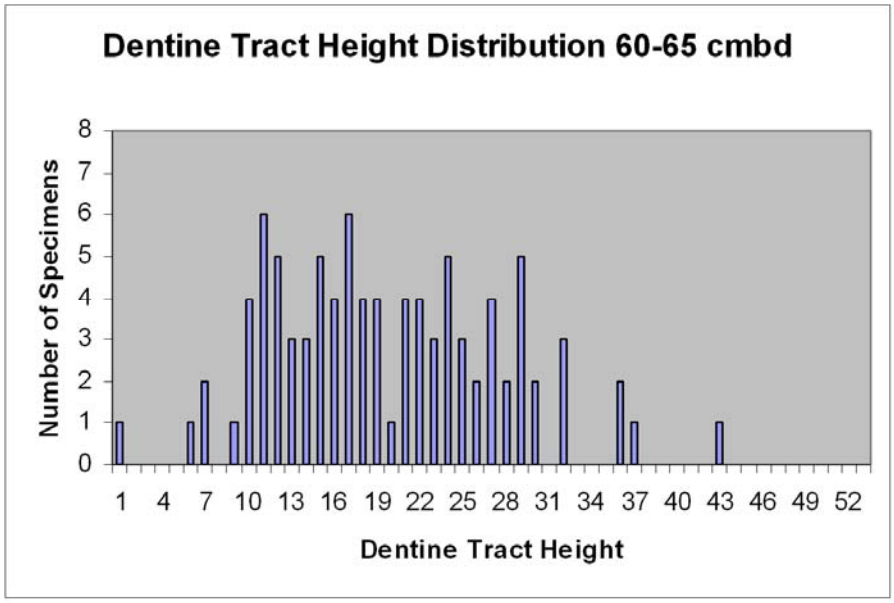


Figure 82. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 60-65 cmbd; n = 91.

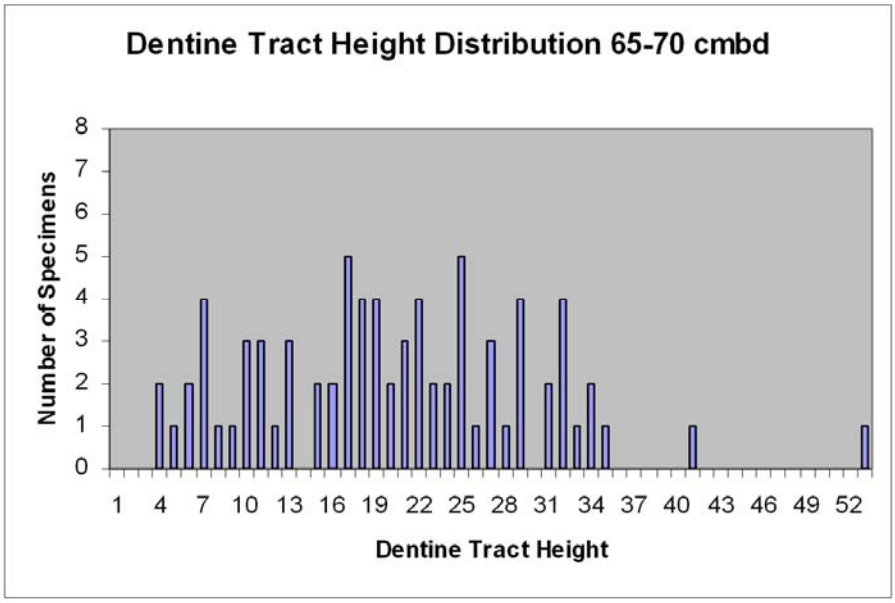


Figure 83. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 65-70 cmbd; n = 77.

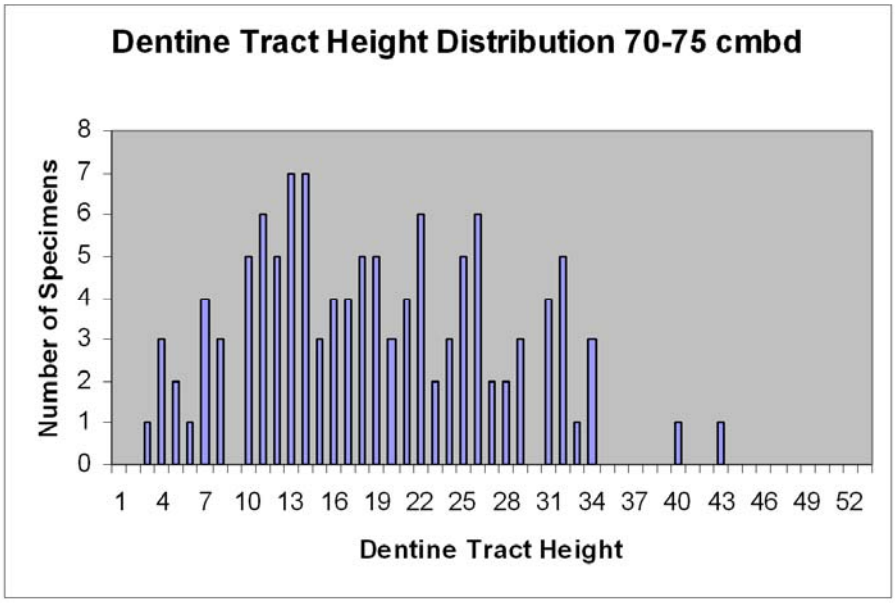


Figure 84. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 70-75 cmbd; n =116.

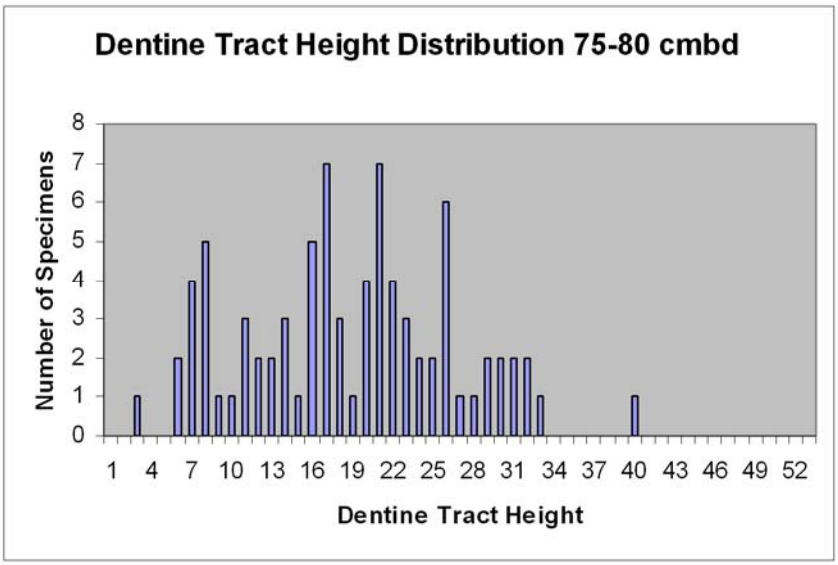


Figure 85. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 75-80 cmbd; n = 81.

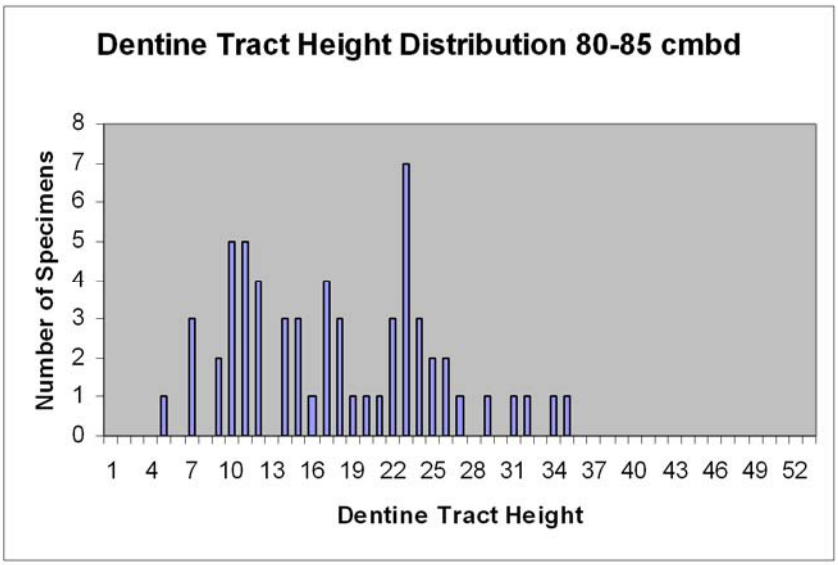


Figure 86. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 80-85 cmbd; n = 60.

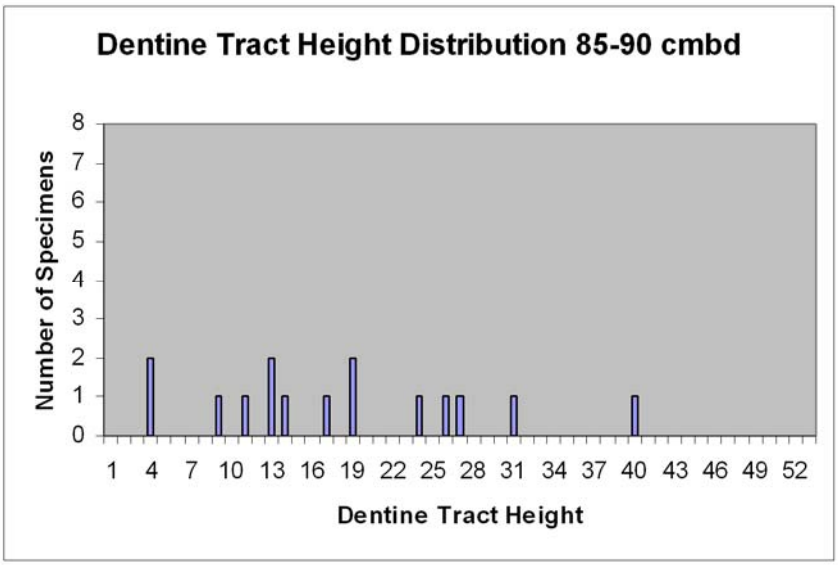


Figure 87. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 85-90 cmbd; n =15.

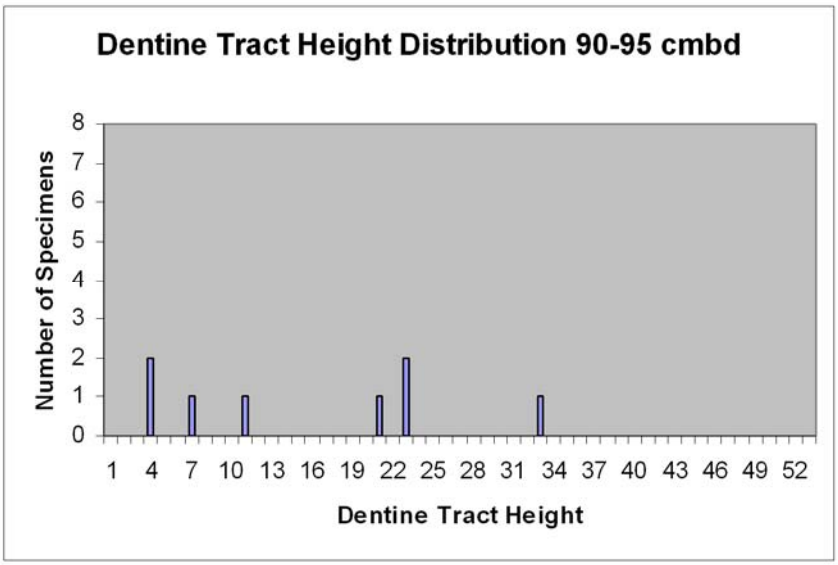


Figure 88. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 90-95 cmbd; n= 8.

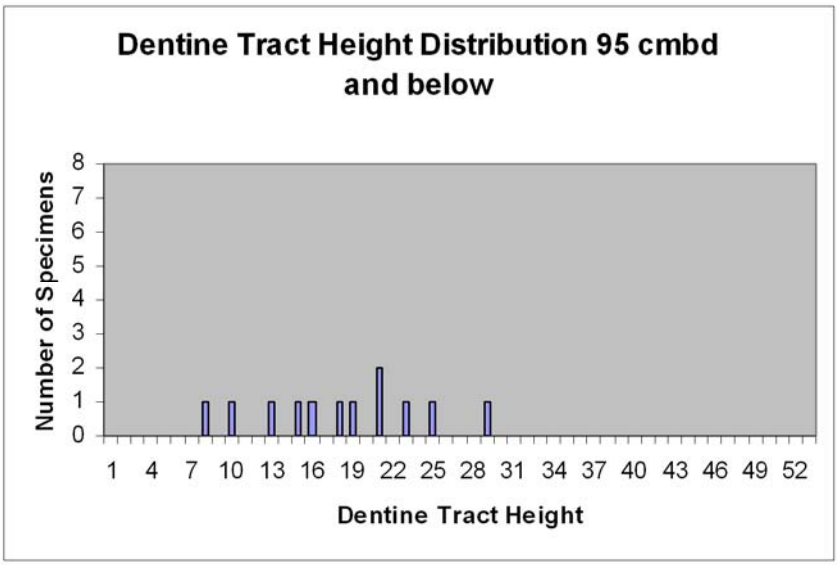


Figure 89. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for 95 cmbd and below; n = 12.

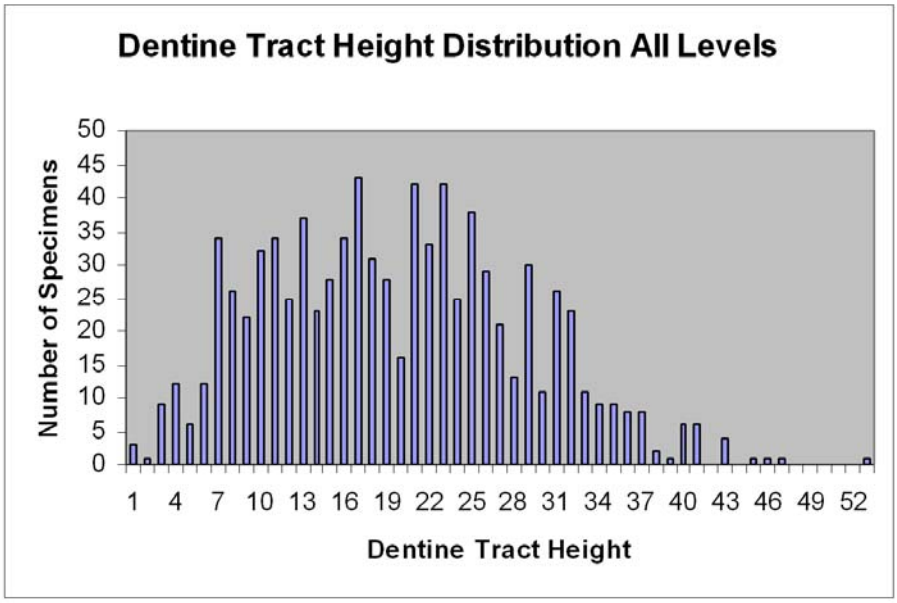


Figure 90. Histogram showing distribution of unique dentine tract heights on m1s of *Neotoma* from Cathedral Cave for all levels; n = 856.

CHAPTER 7: TAXONOMIC RESOLUTION AND BIOTIC CHANGE AT CATHEDRAL CAVE

INTRODUCTION

Our understanding of the interaction between montane environments, climate, and mammal assemblages of the Great Basin provides important insight into mammalian response to climate change. In addition to providing a historical perspective into the development of the modern biota, studies on Pleistocene faunal change may yield predictive power concerning future patterns of faunal response to perturbations in the natural environment (McDonald and Brown, 1992; Barnosky et al., 2003; Barnosky, 2004c). Previous studies concerning biotic change in the Great Basin focused primarily on either fossil faunas of terminal Pleistocene or Holocene-age, or the modern biota (e.g., Brown, 1971, 1978; Grayson, 1993; Lawlor, 1998). Much less work has been conducted to develop our understanding of regional faunal dynamics on a deeper time scale.

Climatic perturbations were common throughout the Pleistocene and are well documented for portions of the Great Basin (Winograd et al., 1988, 1992; Hershler et al., 2002; Wigand and Rhode, 2002; Sharpe, 2007). As such, it seems likely that the composition and geographic distribution of Great Basin mammal assemblages was affected regularly throughout the Pleistocene and not uniquely at the Pleistocene-Holocene transition. However, perceptions of faunal change or stability can be heavily influenced by the degree of taxonomic resolution attained in the fossil identification process (Bell and Gauthier, 2002; Bell et al., 2004c).

In this paper, I review the relationship between taxonomic resolution and our understanding of biogeographic change in the Great Basin. Additionally, I evaluate changes observed in the Cathedral Cave fauna and discuss the possible implications of those changes for our understanding of long-term patterns of biotic change in the region.

SPECIES IDENTIFICATION AND GREAT BASIN BIOGEOGRAPHY

The identification of individual species of mammals assumed a fundamental role in the history of biogeographic research in the Great Basin. Most biogeographic research in the region is rooted in models of island biogeography developed by MacArthur and Wilson (1967), where the number of species on an island is a function of rates of colonization and extinction (Fig. 91a). Island size and the distance of a given island from potential colonizers alter the colonization and extinction curves (Fig. 91b). In his seminal work on biogeography in the Great Basin, Brown (1971, 1978) noted that montane 'islands' in the region retained populations of mammals that were incongruent with the equilibrium conditions set forth in the MacArthur-Wilson models. As a causal mechanism for the non-equilibrium conditions, he invoked greater rates of extinction resulting from changes in Pleistocene-Holocene climate (Brown 1971, 1978). Under this scenario, species that were once widespread throughout the Great Basin were forced into more restricted, high elevation habitats in conjunction with a transition from a Pleistocene (cooler, more mesic) to Holocene (warmer, more aridity) climatic regime.

Brown's non-equilibrium hypothesis had several implications for the fossil record (Grayson, 1993). There should be evidence of montane species at low elevations in the past, there should be evidence of extirpation on individual mountains, there should be

records of extinct species in the region, and there should be no evidence of recent colonization (Grayson, 1993). A significant amount of paleontological research provided evidence to support the first three of these predictions (summarized by Grayson, 1993). However, additional data on modern mammalian distributions in the Great Basin (e.g., Grayson and Livingston, 1993) and further biogeographic analyses (e.g., Lawlor, 1998; Grayson and Madsen, 2000; Floyd et al., 2005) have challenged some of the basic assumptions of the model. Nevertheless, the paradigm established by Brown continues to influence research in the region and played a key role in the initiation of the project discussed here. In 2003, I re-opened paleontological investigations at Cathedral Cave, Nevada, in order to refine the age assignment of the deposit and to evaluate the fauna in the context of Brown's non-equilibrium model.

THE CATHEDRAL CAVE FAUNA AND TAXONOMIC RESOLUTION

Cathedral Cave is located in the northern Snake Range of eastern Nevada (Fig. 1). The cave sits on a north-facing slope near the mouth of Smith Creek Canyon at an elevation of 1950 m. The topographic position of the cave suggests the possibility that fossils contained within the site represent taxa from both the adjacent valley (Spring Valley) and/or taxa inhabiting higher elevations up-slope.

Chronologic analyses indicate a maximum age of between 146.02±2.584 ka to 151.2±4.4 ka for lower portions of the deposit (see Chapter 3). As such, fossils collected from Cathedral Cave allow for the first examination of Pleistocene biotic change in the Great Basin that pre-dates the terminal Pleistocene.

Initial goals for biogeographic research at Cathedral Cave were to utilize all excavated mammal fossils to address certain predictions about regional biogeographic models (i.e., those outlined by Grayson, 1993). I was specifically interested in testing whether the site recorded unique extirpations or extinctions, and whether there was some indication of broad faunal turnover in response to climate change (e.g., major changes in relative abundance of boreal taxa). However, reliable identification of all fossil material in a timely fashion was not possible because of the large number of recovered specimens. Fossil identification was limited to a portion of the fauna deemed useful for addressing chronologic and biogeographic questions (e.g., arvicoline rodents, lagomorphs, and woodrats).

Because of new age data for the locality, and my intent to evaluate the fauna in the context of regional biogeographic models, I took a conservative approach to specimen identification. I tried to restrict identifications to a level permitted by the morphology of the specimens and not limit identifications based on regional geography. To do so would result in circularity in any subsequent biogeographic analyses. Individual criteria used for identification are presented elsewhere (see Chapters 3, 5, and 6).

In the case of pikas (*Ochotona* sp.), some rabbits (*Sylvilagus* or *Lepus* sp.), and woodrats (*Neotoma* sp.) my identifications will likely be deemed as quite conservative. In all likelihood these specimens represent the extant forms living in the Great Basin today. However, the morphology of the specimens, as I understand it, is inadequate to support a species-level assignment. Limiting my comparative sample of species based on modern geographic distribution as a character might improve the taxonomic resolution, but potentially adds bias to my study. While invoking geographic distribution

as a character may seem reasonable for Holocene faunas, and perhaps late Pleistocene faunas, other studies have shown that such an approach can lead to biased data and circularity in subsequent analyses (Bell and Gauthier, 2002; Bever, 2005).

As a result, my approach to identification resulted in data that may not be directly comparable with other Pleistocene localities from the Great Basin. Nearly all Pleistocene-Holocene faunal change data previously reported from the Great Basin rely on species-level identifications. Because independent, species-level resolution was not possible for much of the examined portions of the Cathedral Cave fauna, the analyses presented below potentially offer a new perspective on faunal change in the Great Basin.

MATERIALS AND METHODS

Fossils used to identify potential biotic change in the Cathedral Cave fauna came from a systematic excavation conducted in June of 2003. Matrix was excavated by hand in arbitrary 5-cm levels except in one instance where a discrete sedimentary level was removed as a whole. A total of 226 bags of sediment (one to two gallons) were removed in the excavation process. Sediments were washed through nested coarse and fine screens, and then either sorted immediately or re-bagged for future sorting. All coarse bags were sorted for fossils deemed useful for taxonomic identification (e.g., teeth). One bag of fine matrix was sorted for each unique level. Recovered fossils primarily consisted of isolated elements. Of these, only the elements most commonly cited in species identifications were evaluated (e.g., the m1 in arvicoline rodents). Further details on the field methods and identification process are presented in preceding chapters (Chapters 1, 3, 5, and 6). Taxa used to evaluate faunal change at Cathedral Cave include

arvicoline rodents, lagomorphs, and woodrats. Appendices 5, 8, and 9 list the individual specimens used in the following analyses.

In order to identify distinct episodes of faunal change (e.g., colonization or extinction), I had hoped to collect a sequence of sediments long enough that it might record the appearance and disappearance of taxa. In the absence of a long sequence or such data, relative abundance can be used as a proxy for the identification of changes in the local biota. Certainly, data from the preceding chapters indicate that the taxonomic composition of the sedimentary sequence recovered from Cathedral Cave is fairly homogenous throughout. There do not appear to be distinct colonization or extinction events recorded intermittently throughout the sedimentary sequence from Cathedral Cave. As a result, I chose to examine changes (or lack thereof) in relative abundance in arvicoline rodents and lagomorphs to examine possible responses to climate change in the region. Because no distinct species of *Neotoma* were identified (see Chapter 6), the woodrat fossils have been excluded from further analyses presented here.

Changes in abundance were calculated using number of individual specimens (NISP) and the minimum number of individuals (MNI). Initial abundance calculations were based on NISP. MNI was calculated to determine if patterns of abundance change might simply reflect the use of NISP. Because the record consists predominantly of isolated teeth, the MNI was based on the largest number of specimens of a given tooth (e.g., m1) from given side (i.e., right or left). Only specimens that could be placed into one of the discrete excavation levels considered here (e.g., 40-45 cmbd) were included in relative abundance calculations. The proveniences included in each level are summarized

in Table 18. Appendices 10 and 11 summarize NISP, MNI, and relative abundance for each taxon by excavation level.

RESULTS

Arvicoline Rodents

Figure 92a displays changes in relative abundance based on NISP for arvicoline rodents from Cathedral Cave. Two patterns stand out on the graph. First, the abundance of several extinct taxa (*Microtus paroperarius*, *Microtus meadensis*, and *Phenacomys gryci*) fluctuates in unison in certain instances. This may suggest that populations of these taxa exhibited similar responses to perturbations, climatic or otherwise, in the local environment. Given the temporal persistence of these taxa at Cathedral Cave, they may be good examples of relictual populations in their waning moment. However, samples sizes of these taxa tend to be fairly low.

A more evident pattern is that exhibited by the changes in relative abundance of *Lemmiscus curtatus* and *Microtus* sp. For much of the excavated sequence, there is an inverse relationship in the relative abundance of these taxa (Fig. 92a, b). The relative abundance of *Microtus* sp. increases as the abundance of *Lemmiscus curtatus* decreases and vice versa. This pattern persists up to the cemented level (level 5). A combination of lower sample size and possible sediment mixing above the cemented level may be altering the pattern in levels 1-4.

Because of the greater representation of distinct species of *Microtus*, I recalculated relative abundance for all *Microtus* (*Microtus meadensis, Microtus*

paroperarius, and *Microtus* sp.) to examine the effect on the relative abundance graphs (Figure 93). Interestingly, the pattern does not change, possibly indicating a generic-level response to some external forcing mechanism (e.g., climate change). Although other explanations (population cycling, competitive replacement) may be directly responsible for the pattern observed in this study, those explanations are also closely tied to resource availability and local environmental conditions.

To further verify that the pattern observed represented real biotic change in the record of *Microtus* sp. versus *Lemmiscus curtatus*, I re-calculated abundance data using a sliding scale (Appendix 12). The inverse relationship was evident even at a broader scale (e.g., 10 cm), suggesting that the abundance data represents a real biotic pattern and is not an artifact of excavation sampling (Fig. 94). Additionally, I determined that changes in abundance were statistically significant through use of a g-test, where observed values (i.e., NISP at a given level) were compared to expected values (i.e., overall ratio of *Lemmiscus curtatus* to *Microtus* sp.; see Tables 19-20). Significant differences from expected values were observed for abundance data from both the normal excavation scale (at Levels 7, 9, and 12; Table 19) and sliding scale (at Levels 7-8, 9-10, and 12-13; Table 20).

Lagomorphs

Figure 95 displays changes in relative abundance for lagomorphs from Cathedral Cave. There is an inverse relationship in the abundance of *Ochotona* sp. versus *Sylvilagus* or *Lepus* sp. However, this relationship extends further up (to Level 2) in the excavated sequence than does the inverse relationship of *Microtus* vs. *Lemmiscus*. The

use of NISP versus MNI seems to have no impact on the relationship and this appears to be a pattern occurring at a higher taxonomic level.

DISCUSSION

The Great Basin is a region of high biotic diversity and has been so since the on-set of mountain building in the region (Davis, 2005). Previous attempts to identify patterns of change in mammalian assemblages from the Great Basin were built largely upon species-level analyses. Minimal geographic assumptions (continental-scale) invoked in the identification of Cathedral Cave fossils resulted in fairly conservative identifications for some taxa (e.g., *Ochotona* sp.). Nevertheless, even at higher taxonomic levels there appear to be distinct patterns of faunal change recorded at Cathedral Cave. Calculation and graphing of relative abundance data for lagomorphs and arvicoline rodents from Cathedral Cave result in inverse patterns through time for some taxa. Identifying the exact cause of these relationships is challenging and can only be presented as hypotheses at this point.

Climate and/or environmental change are obviously possible sources for the changes in abundance of lagomorphs and arvicoline rodents observed at Cathedral Cave. The base of the excavated sequence from Cathedral Cave is bracketed between 146.02±2.584 ka to 151.2±4.4 ka. Chronologically, Cathedral Cave is situated in an intermediate climatic framework, near the termination of glacial conditions and near the on-set of interglacial conditions as recorded in various data records from the western United States (Sharpe, 2007). Specific placement of the Cathedral Cave fauna in the

context of those changes is not possible in the absence of additional chronologic control through the excavated sequence.

However, the alternating pattern of *Microtus-Lemmiscus* relative abundance could certainly reflect climatic or environmental fluctuations given the modern habitat affinities of these taxa. Species of *Microtus* commonly inhabit boreal areas in the Great Basin (Hall, 1946) and most species occur in mesic or wet habitats (Getz, 1985). *Lemmiscus curtatus* is commonly associated with sagebrush-steppe environments, although it is known to occur at higher elevations in the Great Basin (Hall, 1946). Portions of western Utah record evidence of a pine woodland-sagebrush steppe mosaic between 130 ka and 150 ka (Davis, 2002) so there were likely suitable habitats present for both taxa. Abundance fluctuations could reflect responses to minor changes in local habitats.

Similarly, *Ochotona* sp. shows an abundance increase relative to *Sylvilagus* or *Lepus* sp. at the same time that *Lemmiscus curtatus* abundance increases. Both living North American species of pika (*Ochotona princeps* and *Ochotona collaris*) are found in areas adjacent to grassy meadows (MacDonald and Jones, 1987; Smith and Weston, 1990). At the least, the abundance data for pikas and voles re-emphasizes the possible importance of individualistic responses at levels above the population, and perhaps species, to climate or environmental change.

With respect to previous interpretations of Pleistocene biotic change in the Great Basin, data from Cathedral Cave are mixed. The presence of extinct taxa (e.g., *Allophaiomys pliocaenicus*, *Microtus paroperarius*, *Microtus meadensis*, *Aztlanolagus agilis*) at Cathedral Cave supports previous biogeographic interpretations. However, I was not able to identify any unique periods of colonization or extirpation within the

excavated sequence itself. Whether this represents a real phenomenon or is simply an artifact of the chronologic length represented by the deposit is unknown. Some taxa do appear intimately tied to higher elevation localities at the time of their latest appearances in the fossil record (e.g., *Allophaiomys pliocaenicus*, *Microtus meadensis* and *M. paroperarius* at Cathedral Cave; *Pliolemmus* at Porcupine Cave [Bell et al., 2004a]) supporting the idea that mountain ranges may act as refugia.

An alternative explanation for the abundance patterns observed here could relate to changes in taphonomic vectors over time. Although a detailed taphonomic analysis of the Cathedral Cave fauna has not yet been conducted, some general trends are evident. Nearly all of the specimens examined for this study represent isolated teeth. Very few complete skulls or dentaries are present. The combined presence of several species of carnivorans, birds, and woodrats suggests that the taphonomic vectors responsible for fossil accumulation in the deposits may have varied over time. If those vectors were preferentially selecting certain taxa at different times, or from different areas adjacent to the cave, it might account for differences in relative abundance.

Future research at Cathedral Cave is necessary to better understand the abundance patterns observed in this study. Isotopic studies could provide data either supporting or refuting perceived changes in local environmental or climatic conditions. For example, oxygen isotope analysis of rodent teeth could provide a proxy for local changes in temperature. Detailed taphonomic analyses will provide a better indication of the factors influencing fossil accumulation through time. Finally, further analyses of the fauna are needed to construct a more complete picture of the biota from Cathedral Cave.

CONCLUSIONS

Species identifications were central to our understanding of biotic change in the Great Basin since James Brown's influential work on mammalian biogeography in the region. Ultimately, our perception of paleobiogeographic change in the region is tied to the primary identifications assigned to individual fossils. Fossils identified from Cathedral Cave represent conservative identifications based on morphology, and continental-scale geographic assumptions. As such, the data presented here may not be directly comparable with similar data from other localities in the region. Nevertheless, the record of extinct taxa and changes in mammalian relative abundance at Cathedral Cave suggests that we may resolve some aspects of biotic change even in instances where species resolution is not possible.

Table 18. List of unique provenience data included in each excavation level used to evaluate relative abundance through time.

Excavation Level	Proveniences Included
1	1N 2E 25-30 cmbd; 1N 3E 25-30 cmbd
2	1N 2E 30-35 cmbd; 1N 3E 30-35 cmbd; 2N 3E 30-35 cmbd
3	1N 2E 35-40 cmbd; 1N 3E 35-40 cmbd; 2N 3E 35-40 cmbd
4	1N 2E 40-45 cmbd; 1N 3E 40-45 cmbd; 2N 3E 40-45 cmbd
5	1N 3E Cemented Level; 2N 2E E Half Cemented Level; 2N 3E Cemented Level
6	1N 2E 45-50 cmbd; 2N 2-3E 45-60 cmbd; 1N 2E 50-55 cmbd; 1N 2E 55-60 cmbd; 1N 3E 55-60 cmbd
7	1N 2E 60-65 cmbd; 1N 3E 60-65 cmbd; 2N 2-3 E 60-65 cmbd
8	1N 2E 65-70 cmbd; 1N 3E 65-70 cmbd; 2N 2-3E 65-70 cmbd
9	1N 2-3E 70-75 cmbd; 2N 2-3E 70-75 cmbd
10	1N 2-3E 75-80 cmbd; 2N 2-3E 75-80 cmbd
11	1N 2-3E 80-85 cmbd; 2N 2-3E 80-85 cmbd
12	1N 2-3E 85-90 cmbd; 2N 2-3E 85-90 cmbd
13	2N 2-3E 90-95 cmbd
14	2N 2-3E 95-102 cmbd; 2N 3E 100-105 cmbd; 2N 3E 105-110 cmbd

Table 19. Summary statistical data for g-test comparison of observed versus predicted abundance of *Microtus* sp. versus *Lemmiscus curtatus* (by excavation level). Obs. n = observed number of specimens. df = degrees of freedom. G = g-test score. Level 1 was excluded because no specimens of *Lemmiscus curtatus* or *Microtus* sp. were identified from that level.

Level/Taxon	Obs. n	Expected Proportions	Expected n	df	G	P-value (two-tailed)
Level 2						
L. curtatus	1	0.432276657	1.05448155	1	0.00594531	0.938539
Microtus sp.	1	0.387608069	0.94551845			
Level 3						
L. curtatus	8	0.432276657	8.43585237	1	0.04756245	0.82736
Microtus sp.	8	0.387608069	7.56414763			
Level 4						
L. curtatus	13	0.432276657	13.1810193			
Microtus sp.	12	0.387608069	11.8189807	1	0.0052559	0.942206
Level 5						
L. curtatus	13	0.432276657	13.1810193			
Microtus sp.	12	0.387608069	11.8189807	1	0.0052559	0.942206
Level 6						
L. curtatus	79	0.432276657	83.3040422	1	0.46967916	0.493135
Microtus sp.	79	0.387608069	74.6959578			
Level 7						
L. curtatus	53	0.432276657	42.1792619	1	6.00738469	0.014246
Microtus sp.	27	0.387608069	37.8207381			
Level 8						
L. curtatus	38	0.432276657	35.3251318	1	0.43014536	0.511918
Microtus sp.	29	0.387608069	31.6748682			
Level 9						
L. curtatus	20	0.432276657	30.5799649	1	7.81521639	0.005181
Microtus sp.	38	0.387608069	27.4200351			

Table 19 continued.

Level 10						
L. curtatus	27	0.432276657	33.2161687	1	2.45904055	0.11685
Microtus sp.	36	0.387608069	29.7838313			
Level 11						
L. curtatus	19	0.432276657	18.4534271	1	0.03428822	0.853095
Microtus sp.	16	0.387608069	16.5465729			
Level 12						
L. curtatus	14	0.432276657	8.43585237	1	8.86277392	0.00291
Microtus sp.	2	0.387608069	7.56414763			
Level 13						
L. curtatus	5	0.432276657	5.27240773	1	0.02972653	0.863112
Microtus sp.	5	0.387608069	4.72759227			
Level 14						
L. curtatus	10	0.432276657	7.38137083	1	2.04376314	0.152831
Microtus sp.	4	0.387608069	6.61862917			

Table 20. Summary statistical data for g-test comparison of observed versus predicted abundance of *Microtus* sp. versus *Lemmiscus curtatus* (over sliding scale). Obs. n = observed number of specimens. df = degrees of freedom. G = g-test score.

Level/Taxon	Obs. n	Expected Proportions	Expected n	df	G	P-value (two-tailed)
Level 1-2						
L. curtatus	1	0.432277	1.054482	1	0.005945	0.938539
Microtus sp.	1	0.3876081	0.945518			
Level 2-3						
L. curtatus	9	0.432277	9.490334	1	0.053508	0.817068
Microtus sp.	9	0.3876081	8.509666			
Level 3-4						
L. curtatus	21	0.432277	21.61687	1	0.0372	0.847058
Microtus sp.	20	0.3876081	19.38313			
Level 4-5						
L. curtatus	26	0.432277	26.36204	1	0.010512	0.918338
Microtus sp.	24	0.3876081	23.63796			
Level 5-6						
L. curtatus	92	0.432277	96.48506	1	0.440389	0.506935
Microtus sp.	91	0.3876081	86.51494			
Level 6-7						
L. curtatus	132	0.432277	125.4833	1	0.717655	0.396914
Microtus sp.	106	0.3876081	112.5167			
Level 7-8						
L. curtatus	91	0.432277	77.50439	1	5.033401	0.024863
Microtus sp.	56	0.3876081	69.49561			
Level 8-9						
L. curtatus	58	0.432277	65.9051	1	2.001783	0.157114
Microtus sp.	67	0.3876081	59.0949			

Table 20 continued.

Level 9-10						
L. curtatus	47	0.432277	63.79613	1	9.380425	0.002193
Microtus sp.	74	0.3876081	57.20387			
Level 10-11						
L. curtatus	46	0.432277	51.6696	1	1.313324	0.251794
Microtus sp.	52	0.3876081	46.3304			
Level 11-12						
L. curtatus	33	0.432277	26.88928	1	2.993219	0.083614
Microtus sp.	18	0.3876081	24.11072			
Level 12-13						
L. curtatus	19	0.432277	13.70826	1	4.522492	0.033452
Microtus sp.	7	0.3876081	12.29174			
Level 13-14						
L. curtatus	15	0.432277	12.65378	1	0.932946	0.334099
Microtus sp.	9	0.3876081	11.34622			

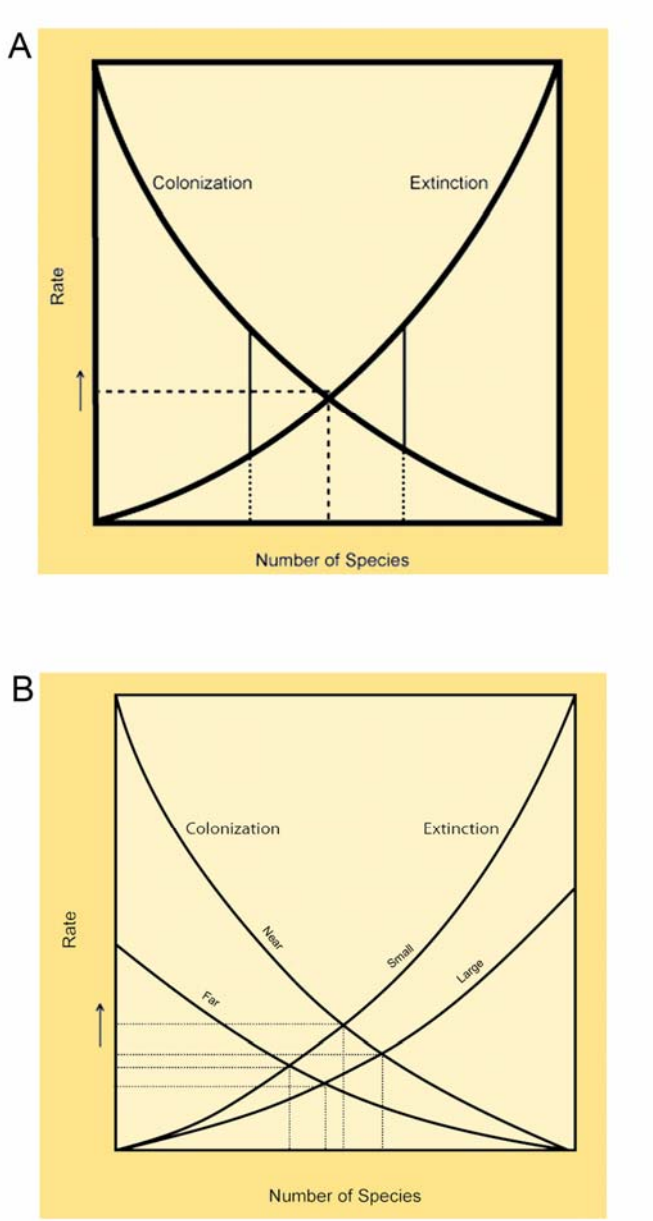


Figure 91. Models of island biogeography simplified from MacArthur and Wilson (1967). A. The relationship between colonization and extinction on islands. B. MacArthur-Wilson Models showing the effect of distance and island size on colonization and extintion curves.

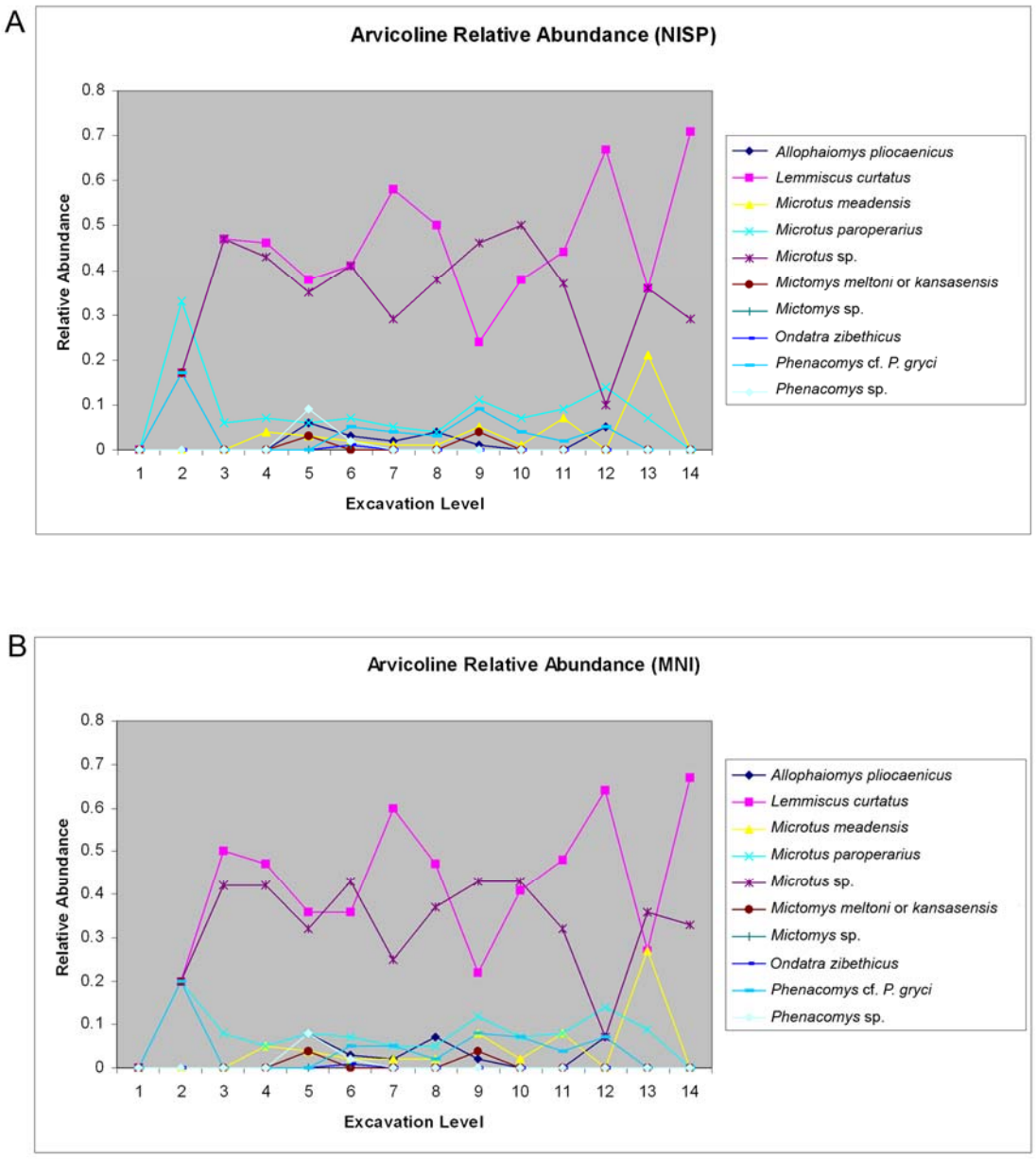


Figure 92. Relative abundance of arvicoline rodents through the excavated sequence at Cathedral Cave. A. Relative abundance based on NISP B. Relative abundance based on MNI.

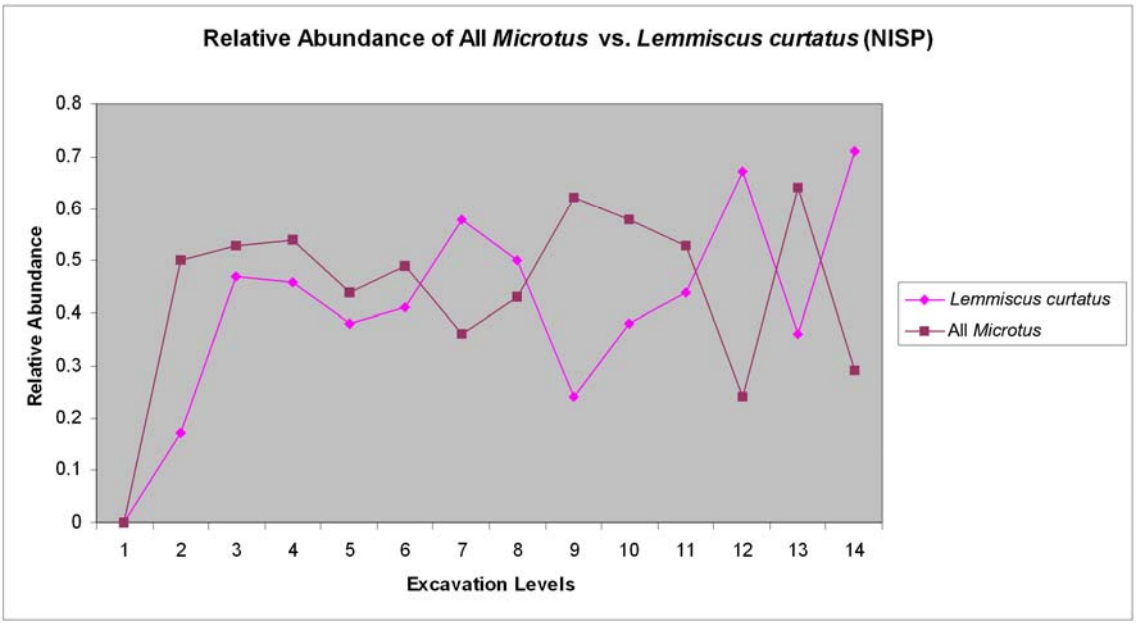


Figure 93. Relative abundance (based on NISP) of all *Microtus* versus *Lemmiscus curtatus* through the excavated sequence at Cathedral Cave.

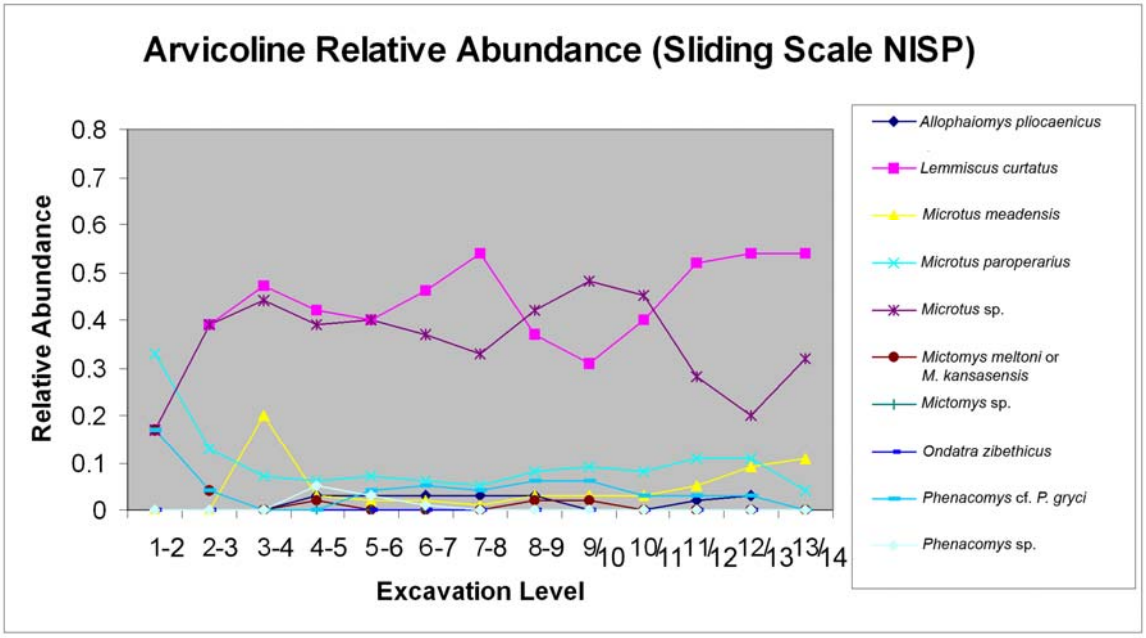


Figure 94. Relative abundance (based on sliding scale and NISP) of all arvicoline rodents through the excavated sequence at Cathedral Cave.

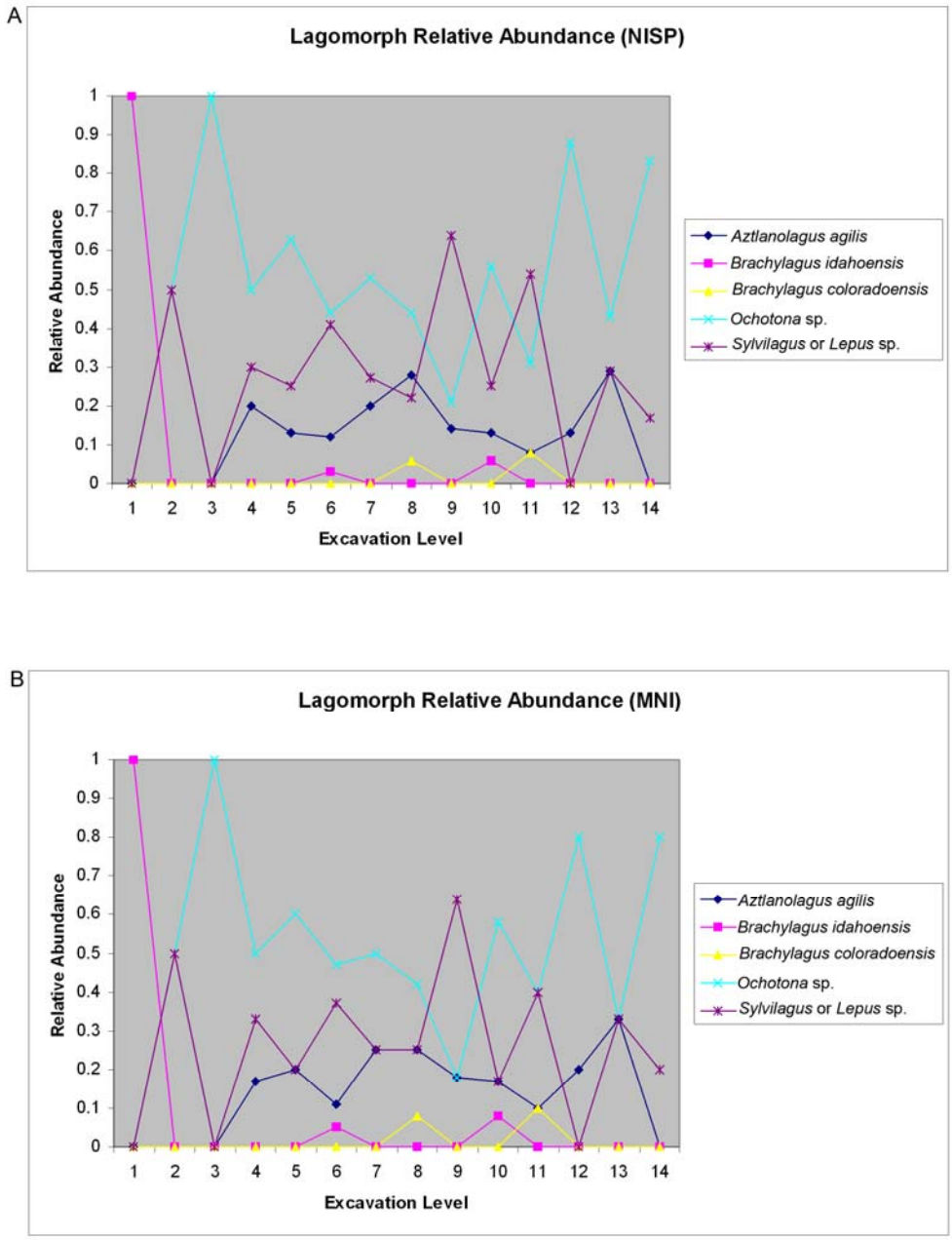


Figure 95. A. Relative abundance of lagomorphs through the excavated sequence at Cathedral Cave. A. Relative abundance based on NISP. B. Relative abundance based on MNI.

Appendix 1. Number of Bags of Excavated Sediment by Excavation Level.

1N 2E 25-30 cmbd: 1 bag; **1N 2E 30-35 cmbd**: 1 bag; **1N 2E 35-40 cmbd**: 1 bag; **1N 2E 40-45 cmbd**: 3 bags; **1N 2E 45-50 cmbd**: 2 bags; **1N 2E 50-55 cmbd**: 3 bags; **1N 2E 55-60 cmbd**: 2 bags; **1N 2E 60-65 cmbd**: 4 bags; **1N 2E Wall Scrapings 25-65 cmbd**: 1 bag; **1N 2E No Provenience**: 1 bag; **1N 2E 65-70 cmbd**: 4 bags; **1N 3E 25-30 cmbd**: 1 bag; **1N 3E 30-35 cmbd**: 4 bags; **1N 3E 35-40 cmbd**: 3 bags; **1N 3E 40-45 cmbd**: 2 bags; **1N 3E Cemented Level**: 8 bags; **1N 3E 43.5-55 cmbd Below Cemented Level**: 11 bags; **1N 3E 45-70 cmbd Wall Collapse**: 1 bag; **1N 3E 55-60 cmbd**: 9 bags; **1N 3E 25-60 cmbd Wall Scrapings**: 6 bags; 1**N 3E 60-65 cmbd**: 9 bags; **1N 3E 65-70 cmbd**: 9 bags; **1N 3E North Wall Scrapings 32-70 cmbd**: 1 bag; **1N 2-3E 70-75 cmbd**: 12 bags; **1N 2-3E 75-80 cmbd**: 4 bags; **1N 2-3E 80-85 cmbd**: 1 bag; **1N 2-3E 85-90 cmbd**: 1 bag; **1N 2-3E 90 cmbd and below**: 1 bag; **2N 2E E Half Upper 50 cm**: 2 bags; **2N 2E E Half Cemented Level**: 2 bags; **2N 3E 30-35 cmbd**: 1 bag; **2N 3E 35-40 cmbd**: 3 bags; **2N 3E 40-45 cmbd**: 9 bags; **2N 3E Cemented Level**: 9 bags; **2N 3E NE Corner "Suspect" 40-56 cmbd**: 1 bag; **2N 2-3E 45-60 cmbd**: 32 bags; **2N 2-3E 60-65 cmbd**: 9 bags; **2N 2-3E 65-70 cmbd**: 9 bags; **2N 2-3E South Wall Scrapings**: 1 bag; **2N 2-3E 70-75 cmbd**: 12 bags; **2N 2-3E 75-80 cmbd**: 10 bags; **2N 2-3E 80-85 cmbd**: 7 bags; **2N 2-3E 85-90 cmbd**: 2 bags; **2N 2-3E 90-95 cmbd**: 2 bags; **2N 2-3E 95-102 cmbd**: 1 bag; **2N 3E Flowstone and Breccia**: 2 bags; **2N 3E 100-105 cmbd**: 2 bags; **2N 3E 105-110 cmbd**: 1 bag; **2N 3E 85-110 cmbd**: 1 bag; **1-2N 2-3E 87-102 cmbd below pedasteled rocks**: 2 bags

Appendix 2. Data Used to Test Correlations Between Body Mass and Cave Representation.

Minimum and maximum body weights are for species irrespective of dimorphism in body weight. Weights for extant taxa are from Wilson and Ruff (1999). Data for *Nothrotheriops shastensis* from Kurten and Anderson (1980). Weights are in kilograms.

Taxon	*C/T*	Min. Body Weight	Max Body Weight
Marsupials			
Didelphis virginiana	0.438	0.3	6.4
Xenarthrans			
Nothrotheriops shastense	0.706	135.0	180.0
Insectivores			
Blarina sp.	0.605	0.006	0.030
Cryptotis parva	0.720	0.003	0.010
Notiosorex crawfordi	0.722	0.003	0.006
Sorex arcticus	0.667	0.005	0.014
Sorex cinereus	0.567	0.002	0.005
Sorex dispar	1.000	0.003	0.008
Sorex fumeus	1.000	0.006	0.011
Sorex hoyi	0.882	0.002	0.007
Sorex palustris	0.619	0.008	0.018
Condylura cristata	0.909	0.040	0.085
Parascalops breweri	1.000	0.041	0.063
Scalopus aquaticus	0.528	0.032	0.140
Chiropterans			
Eptesicus fuscus	0.947	0.011	0.023
Myotis velifer	1.000	0.009	0.014
Pipistrellus subflavus	1.000	0.006	0.010
Carnivores			
Canis latrans	0.545	7.0	20.0
Canis lupus	0.636	23.0	80.0
Urocyon cinereoargenteus	0.579	3.0	7.0
Vulpes velox	0.615	1.4	3.0
Vulpes vulpes	0.765	3.0	7.0
Felis concolor	0.846	29.0	120.0
Lynx rufus	0.769	3.8	31.0
Panthera onca	0.706	31.0	158.0
Lutra Canadensis	0.375	5.0	14.0
Mephitis mephitis	0.704	1.2	5.3
Spilogale putorius	0.792	0.207	0.885

Appendix 2 continued.

Taxon	*C/T*	Min. Body Weight	Max Body Weight
Gulo gulo	0.750	8.3	14.1
Martes Americana	0.867	0.280	1.250
Martes pennanti	0.750	2.0	5.5
Mustela erminea	0.900	0.025	0.116
Mustela frenata	0.739	0.080	0.450
Mustela nigripes	1.000	0.645	1.125
Mustela nivalis	1.000	0.030	0.055
Mustela vison	0.727	0.550	1.250
Taxidea taxus	0.750	na	18.0
Bassariscus astutus	1.000	0.870	1.43
Procyon lotor	0.600	1.8	10.4
Ursus americanus	0.667	39.0	409.0
Ursus arctos	0.833	80.0	600.0
Artiodactyls			
Cervus elaphus	0.750	171.0	497.0
Alces alces	1.000	270.0	600.0
Odocoileus hemionus	0.571	30.0	120.0
Odocoileus virginianus	0.500	22.0	137.0
Rangifer tarandus	0.375	63.0	153.0
Antilocapra americana	0.536	41.0	59.0
Bison bison	0.170	360.0	907.0
Ovis canadensis	0.857	48.0	135.0
Rodents			
Ammospermophilus leucurus	0.667	0.096	0.117
Cynomys leucurus	0.333	0.705	1.675
Cynomys ludovicianus	0.347	0.575	1.49
Marmota flaviventris	0.900	1.6	5.2
Marmota monax	0.824	3.0	4.0
Sciurus carolinensis	0.667	0.338	0.750
Sciurus niger	0.600	0.696	1.233
Spermophilus franklini	0.000	0.340	0.950
Spermophilus lateralis	0.800	0.175	0.350
Spermophilus richardsonii	0.357	0.120	0.745
Spermophilus spilosoma	0.500	0.100	0.200
Spermophilus tridecemlineatus	0.531	0.110	0.280
Spermophilus variegatus	0.900	0.120	0.300
Tamias minimus	0.692	0.032	0.050
Tamias striatus	0.750	0.080	0.150
Tamiasciurus hudsonicus	0.789	0.140	0.250

Appendix 2 continued.

Taxon	*C/T*	Min. Body Weight	Max Body Weight
Glaucomys sabrinus	1.000	0.075	0.140
Glaucomys volans	0.867	0.046	0.085
Castor canadensis	0.435	16.0	30.0
Geomys bursarius	0.346	0.120	0.250
Geomys pinetis	0.500	0.135	0.208
Pappogeomys castanops	1.000	0.225	0.410
Thomomys bottae	0.500	0.080	0.250
Thomomys talpoides	0.370	0.060	0.160
Dipodomys ordii	0.625	0.052	0.052?
Chaetodipus hispidus	0.583	0.030	0.047
Perognathus parvus	0.500	0.017	0.031
Napeozapus insignis	0.909	0.014	0.031
Zapus hudsonius	0.722	0.012	0.030
Zapus princeps	0.500	0.018	0.024
Clethrionomys gapperi	0.720	0.006	0.042
Lemmiscus curtatus	0.765	0.017	0.038
Microtus chrottorrhinus	1.000	0.030	0.048
Microtus longicaudus	0.636	0.036	0.059
Microtus mexicanus	0.857	na	na
Microtus montanus	0.636	0.018	0.090
Microtus ochrogaster	0.450	0.037	0.048
Microtus pennsylvanicus	0.436	0.033	0.065
Microtus pinetorum	0.773	0.014	0.037
Microtus xanthognathus	0.667	0.085	0.158
Neofiber alleni	0.273	0.190	0.350
Ondatra zibethicus	0.380	0.680	1.8
Phenacomys intermedius	0.786	na	0.040
Synaptomys borealis	0.850	0.027	0.035
Synaptomys cooperi	0.556	0.021	0.050
Baiomys taylori	1.000	0.006	0.010
Neotoma albigula	0.700	0.135	0.283
Neotoma cinerea	0.826	0.166	0.585
Neotoma floridana	0.704	0.174	0.384
Neotoma lepida	0.500	0.130	0.160
Neotoma mexicana	1.000	0.151	0.253
Netoma micropus	0.571	0.180	0.317
Onychomys leucogaster	0.333	0.026	0.049
Oryzomys palustris	0.462	0.040	0.080
Peromyscus leucopus	0.588	0.015	0.025

Appendix 2 continued.

Taxon	*C/T*	Min. Body Weight	Max Body Weight
Peromyscus maniculatus	0.577	0.010	0.030
Reithrodontomys megalotis	0.333	0.008	0.015
Sigmodon hispidus	0.519	0.100	0.225
Erethizon dorsatum	0.897	3.5	18.0
Lagomorphs			
Ochotona princeps	0.750	0.121	0.176
Brachylagus idahoensis	0.667	0.373	0.458
Lepus americanus	0.875	0.900	2.200
Lepus californicus	0.700	1.300	3.300
Lepus townsendii	0.571	2.500	4.300
Sylvilagus audubonii	0.583	0.755	1.250
Sylvilagus floridanus	0.583	0.801	1.533
Sylvilagus nuttallii	0.875	0.629	0.871

Appendix 3. Locality Data Used to Construct Locality Maps by Individual Species.

All longitude and latitude data were taken directly from FAUNMAP Working Group (1994). The format for longitude and latitude was converted to a format that could be imported into the map generator maintained by the USGS Woods Hole Science Center (http://woodshole.er.usgs.gov/mapit).

Ammospermophilus leucurus

Locality	Cave/Non-Cave	Longitude	Latitude
Hidden Cave, NV	cave	-118.3700	39.2200
Smith Creek Cave, NV	cave	-114.0500	39.2000
Antelope Cave, CA	cave	-115.3000	35.2200
Kokoweef Cave , CA	cave	-115.3000	35.2500
Smith Creek Canyon Packrat Middens, NV	non-cave	-114.0500	39.2000
Daggett Solid Waste Locality, CA	non-cave	-116.5000	34.5300

Cynomys leucurus

Locality	Cave/Non-Cave	Longitude	Latitude
Horned Owl Cave, WY	cave	-105.3100	41.3400
Rainbow Beach, ID	non-cave	-112.4300	42.5300
Hot Springs Mammoth Site, SD	non-cave	-103.2200	43.2200

Cynomys ludovicianus

Locality	Cave/Non-Cave	Longitude	Latitude
Conkling Cavern, NM	cave	-106.3000	32.1500
Dry Cave, NM	cave	-104.2855	32.2225
Fowlkes Cave, TX	cave	-104.0700	31.0000
Laubach Cave No. 3, TX	cave	-97.3700	30.3700
Cave Without A Name, TX	cave	-98.3700	29.5300
Friesenhahn Cave, TX	cave	-98.2200	29.3700
Laubach Cave No. 1, TX	cave	-97.3700	30.3700
Burnet Cave, NM	cave	-104.4500	32.2200
Montell Shelter, TX	cave	-100.0000	29.3000
Craigmile, IA	non-cave	-95.4407	40.5729
Jones, KS	non-cave	-100.2200	37.0700
Bert Creek No. 9, MT	non-cave	-113.0000	46.3700
Dutton Ranch No. 8, MT	non-cave	-112.5200	46.3700

Appendix 3 continued.

Cynomys ludovicianus (continued)

Locality	Cave/Non-Cave	Longitude	Latitude
Warm Springs #1, MT	non-cave	-112.3700	46.0700
Burnham, OK	non-cave	-99.0000	36.4500
Tesequite Canyon, OK	non-cave	-102.5200	36.5200
Carrol Creek, TX	non-cave	-100.5200	34.5200
Lubbock Lake, TX	non-cave	-101.5331	33.3713
Dutton, CO	non-cave	-102.1500	39.3700
Selby, CO	non-cave	-102.1500	39.5200
Howard Ranch, TX	non-cave	-99.4500	34.2200
Jones-Miller, CO	non-cave	-102.0700	39.5200
Robert, KS	non-cave	-100.2200	37.0100
Blackwater Draw Loc. 1, NM	non-cave	-103.1900	34.1700
Folsom, NM	non-cave	-103.5200	36.4500
Elm Creek Local Fauna, OK	non-cave	-100.3700	36.4500
Lewisville 1978-1980, TX	non-cave	-97.0000	33.0700

Marmota flaviventris

Locality	Cave/Non-Cave	Longitude	Latitude
Rampart Cave, AZ	cave	-113.5600	36.0600
Tse'An Kaetan Cave, AZ	cave	-112.0000	36.0000
Mitchell Caverns, CA	cave	-115.3000	34.5200
Wilson Butte Cave, ID	cave	-114.1300	42.4600
False Cougar Cave, MT	cave	-108.1500	45.0700
Baldy Peak Cave, NM	cave	-107.4500	32.0700
Dark Canyon Cave, NM	cave	-104.3000	32.1500
Hidden Cave, NV	cave	-118.3700	39.2200
Smith Creek Cave, NV	cave	-114.0500	39.2000
Snake Creek Burial Cave, NV	cave	-114.0700	38.5200
Fowlkes Cave, TX	cave	-104.0700	31.0000
Horned Owl Cave, WY	cave	-105.3100	41.3400
Little Box Elder Cave, WY	cave	-105.3700	42.3700
Little Canyon Creek Cave, WY	cave	-107.3700	43.5200
Prospects Shelter, WY	cave	-108.0700	44.5200
Antelope Cave, CA	cave	-115.3000	35.2200
Kokoweef Cave, CA	cave	-115.3000	35.2500
Mescal Cave, CA	cave	-115.3000	35.2200
Dry Cave, NM	cave	-104.2855	32.2225
Vulture Cave, AZ	cave	-113.5600	36.0600

Appendix 3 continued.

Marmota flaviventris (continued)

Locality	Cave/Non-Cave	Longitude	Latitude
Natural Trap Cave, WY	cave	-108.0700	44.5200
Haystack Cave, CO	cave	-107.0700	38.2200
Burnet Cave, NM	cave	-104.4500	32.2200
Fish Bone Cave, NV	cave	-119.1645	40.1208
Dust Cave, TX	cave	-104.4500	31.5200
Upper Sloth Cave, TX	cave	-104.4500	31.5200
Danger Cave, UT	cave	-114.0000	40.3700
Warm Springs #1, MT	non-cave	-112.3700	46.0700
North Cove, NE	non-cave	-99.2200	40.0700
Mercury Ridge, NV	non-cave	-115.5200	36.3700

Marmota monax

Locality	Cave/Non-Cave	Longitude	Latitude
Anderson Pit, IN	cave	-86.3000	39.0000
Cherokee Cave, MO	cave	-90.1300	38.3535
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
New Trout Cave, WV	cave	-79.2208	38.3610
Peccary Cave, AR	cave	-93.0000	35.5200
Clark's Cave, VA	cave	-79.3925	38.0510
Rodgers Shelter, MO	cave	-93.2100	38.0520
Sheriden Pit, OH	cave	-83.2200	40.5200
Hollidaysburg Fissure, PA	cave	-78.2200	40.2200
Meadowcroft Rockshelter, PA	cave	-80.2900	40.1712
New Paris #4, PA	cave	-78.3900	40.0500
Patton Cave, WV	cave	-80.2356	37.3236
Boney Spring, MO	non-cave	-93.2240	38.0610
Prairie Creek, IN	non-cave	-87.1016	38.4251
Kimmswick, MO	non-cave	-90.2305	38.2246

Sciurus carolinensis

Locality	Cave/Non-Cave	Longitude	Latitude
Anderson Pit, IN	cave	-86.3000	39.0000
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Natural Chimneys, VA	cave	-78.0500	38.2200

Appendix 3 continued.

Sciurus carolinensis (continued)

Locality	Cave/Non-Cave	Longitude	Latitude
New Trout Cave, WV	cave	-79.2208	38.3610
Cutler Hammock, FL	cave	-80.1835	25.3640
Monkey Jungle Hammock, FL	cave	-80.2600	25.3400
Clark's Cave, VA	cave	-79.3925	38.0510
Devil's Den, FL	cave	-82.2200	29.2200
Vero 2, FL	non-cave	-80.2415	27.3900
Ichetucknee River 3B, FL	non-cave	-82.4530	29.5830
Kimmswick, MO	non-cave	-90.2305	38.2246
Blackwater Draw Loc. 1, NM	non-cave	-103.1900	34.1700

Sciurus niger

Locality	Cave/Non-Cave	Longitude	Latitude
Anderson Pit, IN	cave	-86.3000	39.0000
Robinson Cave, TN	cave	-85.2225	36.1725
Peccary Cave, AR	cave	-93.0000	35.5200
Cutler Hammock, FL	cave	-80.1835	25.3640
Monkey Jungle Hammock, FL	cave	-80.2600	25.3400
Devil's Den, FL	cave	-82.2200	29.2200
Vero 2, FL	non-cave	-80.2415	27.3900
Boney Spring, MO	non-cave	-93.2240	38.0610
Kimmswick, MO	non-cave	-90.2305	38.2246
Lewisville 1978-1980, TX	non-cave	-97.0000	33.0700

Spermophilus franklini

Locality	Cave/Non-Cave	Longitude	Latitude
Craigmile, IA	non-cave	-95.4407	40.5729
Jones, KS	non-cave	-100.2200	37.0700
Tesequite Canyon, OK	non-cave	-102.5200	36.5200
Clear Creek Local Fauna, TX	non-cave	-97.0000	33.1500
Waubonsie, IA	non-cave	-95.4407	40.5729
Kimmswick, MO	non-cave	-90.2305	38.2246
Elm Creek Local Fauna, OK	non-cave	-100.3700	36.4500
Ben Franklin, TX	non-cave	-95.4500	33.2200

Appendix 3 continued.

Spermophilus lateralis

Locality	Cave/Non-Cave	Longitude	Latitude
Ventana Cave, AZ	cave	-112.1400	32.2000
False Cougar Cave, MT	cave	-108.1500	45.0700
Owl Cave 2, NV	cave	-114.0300	38.5400
Smith Creek Cave, NV	cave	-114.0500	39.2000
Horned Owl Cave, WY	cave	-105.3100	41.3400
Little Box Elder Cave, WY	cave	-105.3700	42.3700
Kokoweef Cave, CA	cave	-115.3000	35.2500
Mescal Cave, CA	cave	-115.3000	35.2200
Smith Creek Canyon Packrat Middens, NV	non-cave	-114.0500	39.2000
Jones-Miller, CO	non-cave	-102.0700	39.5200

Spermophilus richardsoni

Locality	Cave/Non-Cave	Longitude	Latitude
Wilson Butte Cave, ID	cave	-114.1300	42.4600
False Cougar Cave, MT	cave	-108.1500	45.0700
Prospects Shelter, WY	cave	-108.0700	44.5200
Haystack Cave, CO	cave	-107.0700	38.2200
Dry Cave, NM	cave	-104.2855	32.2225
Rainbow Beach, ID	non-cave	-112.4300	42.5300
Jones, KS	non-cave	-100.2200	37.0700
Warm Springs #1, MT	non-cave	-112.3700	46.0700
Smith Springs, NE	non-cave	-101.000	42.3000
Lubbock Lake, TX	non-cave	-101.5331	33.3713
Dutton, CO	non-cave	-102.1500	39.3700
Selby, CO	non-cave	-102.1500	39.5200
Smith Creek Canyon Packrat Middens, NV	non-cave	-114.0500	39.2000
Lange/Ferguson, SD	non-cave	-102.4500	43.1500

Spermophilus spilosoma

Locality	Cave/Non-Cave	Longitude	Latitude
Fowlkes Cave, TX	cave	-104.0700	31.0000
Jones-Miller, CO	non-cave	-102.0700	39.5200

Appendix 3 continued.

Spermophilus townsendii

Locality	Cave/Non-Cave	Longitude	Latitude
Wilson Butte Cave, ID	cave	-114.1300	42.4600
Owl Cave 2, NV	cave	-114.0300	38.5400
Snake Creek Burial Cave, NV	cave	-114.0700	38.5200
Kokoweef Cave, CA	cave	-115.3000	35.2500
Kennewick Roadcut, WA	non-cave	-119.0700	46.0000
Jeppson, WA	non-cave	-119.2100	46.1800
Daggett Solid Waste Locality, CA	non-cave	-116.5000	34.5300

Spermophilus tridecemlineatus

Locality	Cave/Non-Cave	Longitude	Latitude
Bell Cave, AL	cave	-87.4732	34.4346
Eagle Point, IA	cave	-90.1170	41.5415
Anderson Pit, IN	cave	-86.3000	39.0000
False Cougar Cave, MT	cave	-108.1500	45.0700
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Cheek Bend Cave, TN	cave	-86.5200	35.3000
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
Moscow Fissure, WI	cave	-89.5200	42.5200
New Trout Cave, WV	cave	-79.2208	38.3610
Little Box Elder Cave, WY	cave	-105.3700	42.3700
Peccary Cave, AR	cave	-93.0000	35.5200
Dry Cave, NM	cave	-104.2855	32.2225
Clark’s Cave, VA	cave	-79.3925	38.0510
Welsh Cave, KY	cave	-84.4450	37.5225
Hollidaysburg Fissure, PA	cave	-78.2200	40.2200
New Paris #4, PA	cave	-78.3900	40.0500
Craigmile, IA	non-cave	-95.4407	40.5729
Jones, KS	non-cave	-100.2200	37.0700
Smith Springs, NE	non-cave	-101.000	42.3000
Hot Springs Mammoth Site, SD	non-cave	-103.2200	43.2200
Carrol Creek, TX	non-cave	-100.5200	34.5200
Lubbock Lake, TX	non-cave	-101.5331	33.3713
Quitaque Creek, TX	non-cave	-100.3000	34.1500
Jones-Miller, CO	non-cave	-102.0700	39.5200
Brayton, IA	non-cave	-94.5200	41.3700
Waubonsie, IA	non-cave	-95.4407	40.5729

Appendix 3 continued.

Spermophilus tridecemlineatus (continued)

Locality	Cave/Non-Cave	Longitude	Latitude
Robert, KS	non-cave	-100.2200	37.0100
Kimmswick, MO	non-cave	-90.2305	38.2246
North Cove, NE	non-cave	-99.2200	40.0700
Elm Creek Local Fauna, OK	non-cave	-100.3700	36.4500
Lewisville 1978-1980, TX	non-cave	-97.0000	33.0700

Spermophilus variegatus

Locality	Cave/Non-Cave	Longitude	Latitude
False Cougar Cave, MT	cave	-108.1500	45.0700
Dry Cave, NM	cave	-104.2855	32.2225
Fowlkes Cave, TX	cave	-104.0700	31.0000
Little Box Elder Cave, WY	cave	-105.3700	42.3700
Antelope Cave, CA	cave	-115.3000	35.2200
Kokoweef Cave, CA	cave	-115.3000	35.2500
Burnet Cave, NM	cave	-104.4500	32.2200
Dust Cave, TX	cave	-104.4500	31.5200
Upper Sloth Cave, TX	cave	-104.4500	31.5200
Jones-Miller, CO	non-cave	-102.0700	39.5200

Tamias minimus

Locality	Cave/Non-Cave	Longitude	Latitude
Owl Cave 2, NV	cave	-114.0300	38.5400
Smith Creek Cave, NV	cave	-114.0500	39.2000
Little Box Elder Cave, WY	cave	-105.3700	42.3700
Prospects Shelter, WY	cave	-108.0700	44.5200
Peccary Cave, AR	cave	-93.0000	35.5200
Kokoweef Cave, CA	cave	-115.3000	35.2500
Clark’s Cave, VA	cave	-79.3925	38.0510
Natural Trap Cave, WY	cave	-108.0700	44.5200
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Craigmile, IA	non-cave	-95.4407	40.5729
Daggett Solid Waste Locality, CA	non-cave	-116.5000	34.5300
Jones-Miller, CO	non-cave	-102.0700	39.5200
North Cove, NE	non-cave	-99.2200	40.0700

Appendix 3 continued.

Tamias striatus

Locality	Cave/Non-Cave	Longitude	Latitude
Eagle Point, IA	cave	-90.1170	41.5415
Anderson Pit, IN	cave	-86.3000	39.0000
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Cheek Bend Cave, TN	cave	-86.5200	35.3000
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
New Trout Cave, WV	cave	-79.2208	38.3610
Prospects Shelter, WY	cave	-108.0700	44.5200
Peccary Cave, AR	cave	-93.0000	35.5200
Cave Without A Name, TX	cave	-98.3700	29.5300
Clark's Cave, VA	cave	-79.3925	38.0510
Dutchess Quarry Cave, NY	cave	-74.2200	41.2100
Hollidaysburg Fissure, PA	cave	-78.2200	40.2200
Meadowcroft Rockshelter, PA	cave	-80.2900	40.1712
New Paris #4, PA	cave	-78.3900	40.0500
Craigmile, IA	non-cave	-95.4407	40.5729
Boney Spring, MO	non-cave	-93.2240	38.0610
Waubonsie, IA	non-cave	-95.4407	40.5729
Prairie Creek, IN	non-cave	-87.1016	38.4251
Elm Creek Local Fauna, OK	non-cave	-100.3700	36.4500

Tamiasciurus hudsonicus

Locality	Cave/Non-Cave	Longitude	Latitude
Anderson Pit, IN	cave	-86.3000	39.0000
False Cougar Cave, MT	cave	-108.1500	45.0700
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Cheek Bend Cave, TN	cave	-86.5200	35.3000
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
Moscow Fissure, WI	cave	-89.5200	42.5200
New Trout Cave, WV	cave	-79.2208	38.3610
Patton Cave, WV	cave	-80.2356	37.3236
Peccary Cave, AR	cave	-93.0000	35.5200
Clark's Cave, VA	cave	-79.3925	38.0510
Welsh Cave, KY	cave	-84.4450	37.5225
Hollidaysburg Fissure, PA	cave	-78.2200	40.2200
New Paris #4, PA	cave	-78.3900	40.0500

Appendix 3 continued.

Tamiasciurus hudsonicus (continued)

Locality	Cave/Non-Cave	Longitude	Latitude
Dust Cave, TX	cave	-104.4500	31.5200
Brayton, IA	non-cave	-94.5200	41.3700
Waubonsie, IA	non-cave	-95.4407	40.5729
Prairie Creek, IN	non-cave	-87.1016	38.4251
North Cove, NE	non-cave	-99.2200	40.0700

Glaucomys sabrinus

Locality	Cave/Non-Cave	Longitude	Latitude
Cheek Bend Cave, TN	cave	-86.5200	35.3000
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
New Trout Cave, WV	cave	-79.2208	38.3610
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Clark's Cave, VA	cave	-79.3925	38.0510
New Paris #4, PA	cave	-78.3900	40.0500

Glaucomys volans

Locality	Cave/Non-Cave	Longitude	Latitude
Anderson Pit, IN	cave	-86.3000	39.0000
Meadowcroft Rockshelter, PA	cave	-80.2900	40.1712
Baker Bluff Cave, TN	cave	-82.2800	36.2730
Robinson Cave, TN	cave	-85.2225	36.1725
Natural Chimneys, VA	cave	-78.0500	38.2200
New Trout Cave, WV	cave	-79.2208	38.3610
Peccary Cave, AR	cave	-93.0000	35.5200
Cutler Hammock, FL	cave	-80.1835	25.3640
Monkey Jungle Hammock, FL	cave	-80.2600	25.3400
Clark's Cave, VA	cave	-79.3925	38.0510
Devil's Den, FL	cave	-82.2200	29.2200
Dutchess Quarry Cave, NY	cave	-74.2200	41.2100
New Paris #4, PA	cave	-78.3900	40.0500
Ichetucknee River 3B, FL	non-cave	-82.4530	29.5830
Boney Spring, MO	non-cave	-93.2240	38.0610

Appendix 4. Summary of Paleomagnetic Data from Cathedral Cave.

Sample	Demagnetization Step	Declination	Inclination	Intensity
1	AF00	348.2	49.85	9.28E-06
1	AF10	5.0	58.54	1.27E-05
1	AF25	220.8	57.9	1.19E-05
1	AF50	5.0	57.82	1.05E-05
1	AF75	357.2	60.87	9.02E-06
1	AF100	356.1	47.4	6.77E-06
1	AF150	3.7	59.03	4.87E-06
1	AF200	3.4	51.83	4.27E-06
1	AF250	323.1	44.39	3.10E-06
1	AF300	19.8	50.14	3.18E-06
1	AF350	16.0	39.73	4.11E-06
1	AF400	342.5	69.81	2.33E-06
1	AF450	86.4	48.58	1.92E-06
1	AF500	50.2	14.9	9.00E-07
1	AF550	351.6	5.16	2.62E-06
1	AF600	97.0	7.14	2.15E-06
1	AF650	108.0	11.88	3.56E-06
1	AF700	106.5	18.14	3.50E-06
1	AF800	100.6	45.49	2.60E-06
1	AF900	129.4	12.32	2.07E-06
1	AF1000	143.1	32.46	4.29E-06
2	AF00	183.9	50.29	2.35E-05
2	AF10	187.6	52.29	2.32E-05
2	AF25	188.0	51.2	2.23E-05
2	AF50	97.5	51.46	2.01E-05
2	AF75	198.5	47.36	1.64E-05
2	AF100	201.8	44.17	1.49E-05
2	AF150	209.4	48.84	1.27E-05
2	AF200	211.9	45.8	1.06E-05
2	AF250	213.8	40.52	8.73E-06
2	AF300	210.4	44.79	7.78E-06
2	AF350	211.4	44.56	7.35E-06
2	AF400	217.1	47.15	6.20E-06
2	AF450	187.0	50.73	5.29E-06
2	AF500	207.8	41.88	5.42E-06
2	AF550	221.0	39.53	5.02E-06
2	AF600	201.2	36.36	5.80E-06
2	AF650	196.6	44.14	4.47E-06
2	AF700	187.3	37.99	4.60E-06

Appendix 4 continued.

2	AF800	224.8	50.4	3.46E-06
2	AF900	208.0	45.71	3.24E-06
2	AF1000	237.4	39.37	4.32E-06
3	AF00	329.3	42.48	1.45E-05
3	AF10	338.0	35.49	1.48E-05
3	AF25	336.6	36.12	1.39E-05
3	AF50	335.2	29.5	1.21E-05
3	AF75	329.3	31.73	1.00E-05
3	AF100	333.1	28.47	8.33E-06
3	AF150	331.9	31.2	5.58E-06
3	AF200	0.1	72.03	4.68E-06
3	AF250	3.7	74.37	3.75E-06
3	AF300	70.9	59.96	2.39E-06
3	AF350	98.7	67.41	1.96E-06
3	AF400	74.6	61.83	1.85E-06
3	AF450	27.7	56.66	2.22E-06
3	AF500	64.6	65.7	1.54E-06
3	AF550	169.4	65.74	1.56E-06
3	AF600	297.7	68.29	2.21E-06
3	AF650	194.1	21.57	2.33E-06
3	AF700	242.0	55.47	1.83E-06
3	AF800	27.4	8.03	1.16E-05
3	AF900	144.4	-41.98	1.15E-06
3	AF1000	262.3	25.37	2.08E-06
4	AF00	2.4	51.68	2.13E-05
4	AF10	1.3	50.15	2.10E-05
4	AF25	358.3	50.97	1.98E-05
4	AF50	356.9	48.38	1.68E-05
4	AF75	352.9	46.22	1.49E-05
4	AF100	358.8	47.77	1.14E-05
4	AF150	359.2	45.1	8.90E-06
4	AF200	12.6	47.56	6.68E-06
4	AF250	7.4	53.15	6.76E-06
4	AF300	344.9	49.54	5.23E-06
4	AF400	10.0	60.57	4.34E-06
4	AF450	31.7	60.1	3.35E-06
4	AF500	352.0	60.64	2.73E-06
4	AF550	309.3	42.29	2.26E-06
4	AF600	1.3	49.95	2.77E-06
4	AF650	10.1	48.39	2.44E-06

Appendix 4 continued.

4	AF700	348.5	42.04	3.45E-06
4	AF800	201.6	3.54	1.15E-05
4	AF900	308.6	65.22	2.17E-06
4	AF1000	18.7	53.47	1.83E-06

Appendix 5. Complete List of Identified Arvicoline Rodents from Cathedral Cave.

The discrepancy between the sample size listed in the text (n = 844) and that presented here (n = 845) results from the inclusion of an M2 of *Ondatra* (TMM 43693-2693) in the appendix. TMM 43693-2693 was included here because this specimen was distinctly larger than other taxa and was included in the initial identification process. S = side. # = unique specimen number associated with Cathedral Cave locality number TMM 43693 (i.e., TMM 43693-1921 is the full number for the first specimen listed below. Where relevant to discussions in the text, data on the number and relative closure of triangles are included under the 'Morphotype' heading. Two specimens identified as *Microtus* sp. but with a poor state of preservation are designated with 'preservation' in the morphotype column.

#	Taxon	S	Element	Morphotype	Provenience	Comments
1921	*Allophaiomys pliocaenicus*	L	m1		1N 3E Cemented Level	
1922	*Allophaiomys pliocaenicus*	L	m1		2N 3E Cemented Level	
1923	*Allophaiomys pliocaenicus*	R	m1		2N 2-3E 45-60 cmbd	
254	*Allophaiomys pliocaenicus*	R	m1		2N 2-3E 45-60 cmbd	
1924	*Allophaiomys pliocaenicus*	L	m1		2N 2-3E 45-60 cmbd	
1925	*Allophaiomys pliocaenicus*	L	m1	T4 narrowly confluent w/ T5 anterior cap	1N 2E 55-60 cmbd	
1926	*Allophaiomys pliocaenicus*	L	m1		1N 2E 55-60 cmbd	
1927	*Allophaiomys pliocaenicus*	R	m1		1N 3E 55-60 cmbd	
1928	*Allophaiomys pliocaenicus*	L	m1		1N 2E 60-65 cmbd	
1929	*Allophaiomys pliocaenicus*	R	m1		2N 2-3 E 60-65 cmbd	
1930	*Allophaiomys pliocaenicus*	L	m1		1N 2E 65-70 cmbd	
1931	*Allophaiomys pliocaenicus*	L	m1		1N 3E 65-70 cmbd	
1932	*Allophaiomys pliocaenicus*	L	dentary with m1-2		2N 2-3E 65-70 cmbd	
1933	*Allophaiomys pliocaenicus*	R	m1	T4 narrowly confluent w/ T5 anterior cap	1N 2-3E 70-75 cmbd	
1934	*Allophaiomys pliocaenicus*	R	m1		1N 2-3E 85-90 cmbd	
1935	*Allophaiomys pliocaenicus*	L	m1		2N 2-3E 85-90 cmbd and below	
1936	*Arvicolinae*	?	m1		1N 3E 45-70 cmbd; wall collapse	
1937	*Arvicolinae*	R	m1		1N 3E 25-30 cmbd	fragment
1938	*Arvicolinae*	L	m1?		1N 3E 35-40 cmbd	
1939	*Arvicolinae*	?	m1		1N 3E Cemented Level	fragment
1940	*Arvicolinae*	R	partial m1		2N 3E Cemented Level	
1941	*Arvicolinae*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	fragment
1942	*Arvicolinae*	R	m1		1N 3E 43.5-55 cmbd, below cemented level	damaged
1943	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	partial
1944	*Arvicolinae*	?	m1		2N 2-3E 45-60 cmbd	fragment
1945	*Arvicolinae*	L	dentary with i1, m1		2N 2-3E 45-60 cmbd	m1 broken
1946	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	
1947	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	
221	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	partial
269	*Arvicolinae*	R	m1		2N 2-3E 45-60 cmbd	partial
277	*Arvicolinae*	?	m1		2N 2-3E 45-60 cmbd	partial
312	*Arvicolinae*	?	m1		2N 2-3E 45-60 cmbd	partial
1948	*Arvicolinae*	R	m1		2N 2-3E 45-60 cmbd	partial

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
1949	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	
1950	*Arvicolinae*	L	m1		2N 2-3E 45-60 cmbd	
1951	*Arvicolinae*	-	m1		1N 2E 50-55 cmbd	
1952	*Arvicolinae*	-	m1		1N 2E 50-55 cmbd	fragment
1953	*Arvicolinae*	R	m1		1N 2E 60-65 cmbd	
1954	*Arvicolinae*	L	m1		1N 3E 60-65 cmbd	fragment
1955	*Arvicolinae*	?	m1		2N 2-3E 60-65 cmbd	fragment
1956	*Arvicolinae*	?	m1		2N 2-3E 60-65 cmbd	fragment
1957	*Arvicolinae*	R	m1		1N 2E 65-70 cmbd	
1958	*Arvicolinae*	L	m1		2N 2-3E 65-70 cmbd	fragment
1959	*Arvicolinae*	?	m1		2N 2-3E 65-70 cmbd	partial
1960	*Arvicolinae*	L	m1		2N 2-3E 65-70 cmbd	fragment
1961	*Arvicolinae*	L	m1		2N 2-3E 65-70 cmbd	fragment
1962	*Arvicolinae*		m1		2N 2-3E 65-70 cmbd	fragment
1963	*Arvicolinae*	?	m1		1N 2-3E 70-75 cmbd	fragment
1964	*Arvicolinae*	R	m1		2N 2-3E 70-75 cmbd	partial
1965	*Arvicolinae*	?	m1		2N 2-3E 70-75 cmbd	fragment
1966	*Arvicolinae*	L	m1		1N 2-3E 75-80 cmbd	fragment
1967	*Arvicolinae*	?	m1		1N 2-3E 75-80 cmbd	fragment
1968	*Arvicolinae*	?	m1		2N 2-3E 75-80 cmbd	fragment
1969	*Arvicolinae*	?	m1		2N 2-3E 75-80 cmbd	fragment
1970	*Arvicolinae*	?	m1		2N 2-3E 75-80 cmbd	fragment
1971	*Arvicolinae*	?	m1		1N 2-3E 85-90 cmbd	fragment
1972	*Arvicolinae*	R	m1		1N 2-3E 85-90 cmbd	partial
1973	*Arvicolinae*	?	m1		2N 3E 85-110 cmbd, below flowstone	partial
1974	*Arvicolinae*	?	m1		2N 3E 85-110 cmbd, below flowstone	partial
1975	*Arvicolinae*	R	dentary with m1		2N 3E 100-105 cmbd	heavily worn
1976	*Lemmiscus curtatus*	L	m1		1N 2E No Provenience; under big rock	
1977	*Lemmiscus curtatus*	R	m1	T6 pinched	2N 2E E Half, Upper 50 cm	
1978	*Lemmiscus curtatus*	R	dentary with i1, m1-3		1N 2E 25-65 cmbd; wall scrapings	
1979	*Lemmiscus curtatus*	L	m1		1N 3E 25-60 cmbd; E wall scrapings	partial
1980	*Lemmiscus curtatus*	R	m1		1N 3E wall collapse; less than 70 cmbd	
1981	*Lemmiscus curtatus*	L	m1		1N 3E wall collapse; less than 70 cmbd	
1982	*Lemmiscus curtatus*	L	partial dentary with i1, m1-2		2N 3E 40-56 cmbd; NE corner suspect	
1983	*Lemmiscus curtatus*	R	m1		2N 3E 40-56 cmbd; NE corner suspect	
1984	*Lemmiscus curtatus*	R	m1		2N 3E 40-56 cmbd; NE corner suspect	
1985	*Lemmiscus curtatus*	R	m1		2N 3E 40-56 cmbd; NE corner suspect	
1986	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-75 cmbd; S wall scrapings	
1987	*Lemmiscus curtatus*	R	m1		1N 3E 30-35 cmbd	
1988	*Lemmiscus curtatus*	R	m1		1N 2E 35-40 cmbd	
1989	*Lemmiscus curtatus*	R	m1		1N 2E 35-40 cmbd	
1990	*Lemmiscus curtatus*	L	m1	4T	1N 2E 35-40 cmbd	
1991	*Lemmiscus curtatus*	R	m1		1N 2E 35-40 cmbd	digested
1992	*Lemmiscus curtatus*	R	m1		1N 3E 35-40 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
1993	*Lemmiscus curtatus*	L	m1		2N 3E 35-40 cmbd	
1994	*Lemmiscus curtatus*	R	m1		2N 3E 35-40 cmbd	
1995	*Lemmiscus curtatus*	R	m1		2N 3E 35-40 cmbd	
1996	*Lemmiscus curtatus*	R	m1		1N 3E 40-45 cmbd	
1997	*Lemmiscus curtatus*	R	m1	5T?	1N 3E 40-45 cmbd	
1998	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
1999	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
2000	*Lemmiscus curtatus*	L	dentary with m1		2N 3E 40-45 cmbd	partial
2001	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
2002	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
2003	*Lemmiscus curtatus*	R	m1		2N 3E 40-45 cmbd	juvenile?
2004	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
2005	*Lemmiscus curtatus*	R	dentary with i1, m1-m2		2N 3E 40-45 cmbd	partial, digested?
2006	*Lemmiscus curtatus*	L	m1		2N 3E 40-45 cmbd	
2007	*Lemmiscus curtatus*	L	dentary with m1-m2		2N 3E 40-45 cmbd	partial
2008	*Lemmiscus curtatus*	L	m1	4T	2N 3E 40-45 cmbd	
2009	*Lemmiscus curtatus*	L	m1		1N 3E Cemented Level	broken
2010	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	1N 3E Cemented Level	
2011	*Lemmiscus curtatus*	L	partial dentary with i1, m1	T6 pinched	1N 3E Cemented Level	
2012	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	1N 3E Cemented Level	digested
2013	*Lemmiscus curtatus*	L	m1		2N 3E Cemented Level	
2014	*Lemmiscus curtatus*	L	m1		2N 3E Cemented Level	
2015	*Lemmiscus curtatus*	R	dentary with i1, m1		2N 3E Cemented Level	
2016	*Lemmiscus curtatus*	L	m1		2N 3E Cemented Level	
2017	*Lemmiscus curtatus*	R	m1		2N 3E Cemented Level	digested
2018	*Lemmiscus curtatus*	L	m1		2N 3E Cemented Level	digested
2019	*Lemmiscus curtatus*	L	dentary with m1-m2		2N 3E Cemented Level	partial
2020	*Lemmiscus curtatus*	R	m1		2N 3E Cemented Level	
2021	*Lemmiscus curtatus*	R	m1		2N 2E E Half Cemented Level	
2022	*Lemmiscus curtatus*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2023	*Lemmiscus curtatus*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2024	*Lemmiscus curtatus*	R	m1	4T	1N 3E 43.5-55 cmbd; below cemented level	
2025	*Lemmiscus curtatus*	R	m1	6T	1N 3E 43.5-55 cmbd; below cemented level	
2026	*Lemmiscus curtatus*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2027	*Lemmiscus curtatus*	R	partial m1	preservation	1N 3E 43.5-55 cmbd; below cemented level	
2028	*Lemmiscus curtatus*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	
2029	*Lemmiscus curtatus*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2030	*Lemmiscus curtatus*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2031	*Lemmiscus curtatus*	L	partial dentary with m1		1N 3E 43.5-55 cmbd; below cemented level	
2032	*Lemmiscus curtatus*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	
2033	*Lemmiscus curtatus*	L	m1	4T	1N 3E 43.5-55 cmbd; below cemented level	
2034	*Lemmiscus curtatus*	R	partial dentary with m1		1N 3E 43.5-55 cmbd; below cemented level	
2035	*Lemmiscus curtatus*	L	m1		1N 3E 43.5-55 cmbd, below cemented level	
2036	*Lemmiscus curtatus*	L	m1		1N 3E 43.5-55 cmbd, below cemented level	juvenile
2037	*Lemmiscus curtatus*	R	m1		1N 3E 43.5-55 cmbd, below cemented level	
2038	*Lemmiscus curtatus*	L	dentary with i1, m1	6T	1N 3E 43.5-55 cmbd, below cemented level	partial
2039	*Lemmiscus curtatus*	R	m1		1N 2E 45-50 cmbd	
2040	*Lemmiscus curtatus*	R	partial dentary with m1		1N 2E 45-50 cmbd	
2041	*Lemmiscus curtatus*	R	m1		1N 2E 45-50 cmbd	
197	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
199	*Lemmiscus curtatus*	L	m1	4T	2N 2-3E 45-60 cmbd	
219	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
235	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
272	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
319	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2042	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2043	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2044	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2045	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	2N 2-3E 45-60 cmbd	
2046	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2047	*Lemmiscus curtatus*	R	m1	4T, T5 with incipient closure	2N 2-3E 45-60 cmbd	
2048	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2049	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2050	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2051	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2052	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2053	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2054	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2055	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2056	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2057	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2058	*Lemmiscus curtatus*	R	dentary with i1, m1		2N 2-3E 45-60 cmbd	
2059	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2060	*Lemmiscus curtatus*	L	dentary with m1-2		2N 2-3E 45-60 cmbd	
2061	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2062	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2063	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2064	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2065	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2066	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2067	*Lemmiscus curtatus*	R	dentary with m1		2N 2-3E 45-60 cmbd	partial
2068	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2069	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	partial

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2070	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2071	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2072	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2073	*Lemmiscus curtatus*	R	m1	4T	2N 2-3E 45-60 cmbd	
2074	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2075	*Lemmiscus curtatus*	L	dentary with i1, m1-2	4T	2N 2-3E 45-60 cmbd	
2076	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2077	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2078	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2079	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2080	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2081	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2082	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2083	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2084	*Lemmiscus curtatus*	R	m1	4T	2N 2-3E 45-60 cmbd	digested
2085	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2086	*Lemmiscus curtatus*	R	dentary with m1		2N 2-3E 45-60 cmbd	partial
2087	*Lemmiscus curtatus*	L	dentary with m1		2N 2-3E 45-60 cmbd	partial
2088	*Lemmiscus curtatus*	L	m1		2N 2-3E 45-60 cmbd	
2089	*Lemmiscus curtatus*	R	m1		2N 2-3E 45-60 cmbd	
2090	*Lemmiscus curtatus*	R	m1	4T	1N 2E 50-55 cmbd	
2091	*Lemmiscus curtatus*	R	m1		1N 2E 50-55 cmbd	
2092	*Lemmiscus curtatus*	L	m1		1N 2E 50-55 cmbd	broken
2093	*Lemmiscus curtatus*	R	dentary with i1, m1-2		1N 2E 50-55 cmbd	
2094	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	1N 2E 50-55 cmbd	
2095	*Lemmiscus curtatus*	L	m1		1N 2E 50-55 cmbd	
2096	*Lemmiscus curtatus*	L	m1	4T, 5T pinched	1N 2E 50-55 cmbd	
2097	*Lemmiscus curtatus*	R	m1		1N 2E 50-55 cmbd	
2098	*Lemmiscus curtatus*	L	dentary with m1		1N 2E 55-60 cmbd	partial
2099	*Lemmiscus curtatus*	L	m1		1N 2E 55-60 cmbd	
2100	*Lemmiscus curtatus*	L	m1		1N 2E 55-60 cmbd	digested
2101	*Lemmiscus curtatus*	R	m1		1N 2E 55-60 cmbd	
2102	*Lemmiscus curtatus*	L	m1		1N 2E 55-60 cmbd	
2103	*Lemmiscus curtatus*	R	m1		1N 2E 55-60 cmbd	
2104	*Lemmiscus curtatus*	L	m1	4T	1N 3E 55-60 cmbd	
2105	*Lemmiscus curtatus*	R	m1		1N 3E 55-60 cmbd	
2106	*Lemmiscus curtatus*	L	m1		1N 3E 55-60 cmbd	broken
2107	*Lemmiscus curtatus*	L	m1		1N 3E 55-60 cmbd	
2108	*Lemmiscus curtatus*	R	m1		1N 3E 55-60 cmbd	
2109	*Lemmiscus curtatus*	L	m1		1N 3E 55-60 cmbd	
2110	*Lemmiscus curtatus*	L	m1		1N 3E 55-60 cmbd	
2111	*Lemmiscus curtatus*	L	m1		1N 3E 55-60 cmbd	
2112	*Lemmiscus curtatus*	L	m1		1N 2E 60-65 cmbd	
2113	*Lemmiscus curtatus*	L	dentary with i1, m1-2		1N 2E 60-65 cmbd	
2114	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	1N 2E 60-65 cmbd	
2115	*Lemmiscus curtatus*	R	dentary with i1, m1		1N 2E 60-65 cmbd	
2116	*Lemmiscus curtatus*	L	m1	T6 pinched	1N 2E 60-65 cmbd	
2117	*Lemmiscus curtatus*	R	m1		1N 2E 60-65 cmbd	digested?
2118	*Lemmiscus curtatus*	R	m1		1N 2E 60-65 cmbd	
2119	*Lemmiscus curtatus*	L	m1		1N 2E 60-65 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2120	*Lemmiscus curtatus*	R	m1		1N 2E 60-65 cmbd	
2121	*Lemmiscus curtatus*	L	m1	4T	1N 2E 60-65 cmbd	
2122	*Lemmiscus curtatus*	R	m1		1N 2E 60-65 cmbd	
2123	*Lemmiscus curtatus*	L	m1		1N 2E 60-65 cmbd	
2124	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
1651	*Lemmiscus curtatus*	L	m1		1N 3E 60-65 cmbd	
1659	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
2125	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	partial
2126	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
2127	*Lemmiscus curtatus*	L	m1		1N 3E 60-65 cmbd	
1673	*Lemmiscus curtatus*	L	m1		1N 3E 60-65 cmbd	
2128	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
2129	*Lemmiscus curtatus*	L	m1		1N 3E 60-65 cmbd	
2130	*Lemmiscus curtatus*	R	dentary with m1-m2		1N 3E 60-65 cmbd	partial
2131	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
2132	*Lemmiscus curtatus*	R	m1		1N 3E 60-65 cmbd	
2133	*Lemmiscus curtatus*	R	m1	4T	2N 2-3 E 60-65 cmbd	
2134	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2135	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2136	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2137	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2138	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2139	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2140	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2141	*Lemmiscus curtatus*	R	dentary with m1		2N 2-3 E 60-65 cmbd	
2142	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2143	*Lemmiscus curtatus*	R	dentary with m1		2N 2-3 E 60-65 cmbd	
2144	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	partial
2145	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	digested
2146	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2147	*Lemmiscus curtatus*	R	dentary with m1-2		2N 2-3 E 60-65 cmbd	partial
2148	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2149	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2150	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	2N 2-3 E 60-65 cmbd	
2151	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2152	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2153	*Lemmiscus curtatus*	R	dentary with m1-2		2N 2-3 E 60-65 cmbd	partial
2154	*Lemmiscus curtatus*	R	m1		2N 2-3 E 60-65 cmbd	
2155	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	2N 2-3 E 60-65 cmbd	digested?
2156	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2157	*Lemmiscus curtatus*	L	m1		2N 2-3 E 60-65 cmbd	
2158	*Lemmiscus curtatus*	L	m1		2N 2-3E 60-65 cmbd	
2159	*Lemmiscus curtatus*	R	m1		2N 2-3E 60-65 cmbd	
2160	*Lemmiscus curtatus*	R	m1		2N 2-3E 60-65 cmbd	
2161	*Lemmiscus curtatus*	R	m1		2N 2-3E 60-65 cmbd	
2162	*Lemmiscus curtatus*	R	m1		1N 2E 65-70 cmbd	
2163	*Lemmiscus curtatus*	R	dentary with m1	4T	1N 2E 65-70 cmbd	
2164	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	1N 2E 65-70 cmbd	
2165	*Lemmiscus curtatus*	L	m1		1N 2E 65-70 cmbd	
2166	*Lemmiscus curtatus*	L	m1		1N 2E 65-70 cmbd	
2167	*Lemmiscus curtatus*	L	m1		1N 2E 65-70 cmbd	
2168	*Lemmiscus curtatus*	L	m1		1N 2E 65-70 cmbd	
2169	*Lemmiscus curtatus*	R	m1	4T	1N 2E 65-70 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2170	*Lemmiscus curtatus*	R	m1		1N 2E 65-70 cmbd	
2171	*Lemmiscus curtatus*	R	m1		1N 2E 65-70 cmbd	
2172	*Lemmiscus curtatus*	L	m1		1N 2E 65-70 cmbd	digested
2173	*Lemmiscus curtatus*	R	m1		1N 2E 65-70 cmbd	
2174	*Lemmiscus curtatus*	R	dentary with m1		1N 2E 65-70 cmbd	partial
1444	*Lemmiscus curtatus*	L	m1		1N 3E 65-70 cmbd	digested
1482	*Lemmiscus curtatus*	R	dentary with i1, m1-2	4T	1N 3E 65-70 cmbd	
2175	*Lemmiscus curtatus*	L	m1		1N 3E 65-70 cmbd	
2176	*Lemmiscus curtatus*	L	m1		1N 3E 65-70 cmbd	digested?
2177	*Lemmiscus curtatus*	L	m1		1N 3E 65-70 cmbd	
2178	*Lemmiscus curtatus*	L	m1		2N 2-3E 65-70 cmbd	digested?
2179	*Lemmiscus curtatus*	L	m1		2N 2-3E 65-70 cmbd	
2180	*Lemmiscus curtatus*	L	m1	4T	2N 2-3E 65-70 cmbd	
2181	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2182	*Lemmiscus curtatus*	R	m1	4T	2N 2-3E 65-70 cmbd	
2183	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2184	*Lemmiscus curtatus*	L	m1		2N 2-3E 65-70 cmbd	
2185	*Lemmiscus curtatus*	L	m1		2N 2-3E 65-70 cmbd	
2186	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2187	*Lemmiscus curtatus*	L	dentary with i1, m1-2		2N 2-3E 65-70 cmbd	
2188	*Lemmiscus curtatus*	L	m1		2N 2-3E 65-70 cmbd	
2189	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2190	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	2N 2-3E 65-70 cmbd	
2191	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2192	*Lemmiscus curtatus*	R	m1	4T	2N 2-3E 65-70 cmbd	
2193	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2194	*Lemmiscus curtatus*	L	dentary with m1-2		2N 2-3E 65-70 cmbd	partial
2195	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2196	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2197	*Lemmiscus curtatus*	R	m1		2N 2-3E 65-70 cmbd	
2198	*Lemmiscus curtatus*	R	m1		1N 2-3E 70-75 cmbd	
713	*Lemmiscus curtatus*	L	m1		1N 2-3E 70-75 cmbd	
2199	*Lemmiscus curtatus*	R	dentary with i1, m1		1N 2-3E 70-75 cmbd	partial
2200	*Lemmiscus curtatus*	R	m1		1N 2-3E 70-75 cmbd	digested?
2201	*Lemmiscus curtatus*	L	m1		1N 2-3E 70-75 cmbd	
2202	*Lemmiscus curtatus*	R	m1	T6 with incipient closure	2N 2-3E 70-75 cmbd	
2203	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2204	*Lemmiscus curtatus*	R	m1	5T, T6 pinched	2N 2-3E 70-75 cmbd	
2205	*Lemmiscus curtatus*	R	m1		2N 2-3E 70-75 cmbd	
2206	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2207	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2208	*Lemmiscus curtatus*	L	dentary with i1, m1-2	6T	2N 2-3E 70-75 cmbd	
2209	*Lemmiscus curtatus*	R	m1		2N 2-3E 70-75 cmbd	
2210	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2211	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2212	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	digested
2213	*Lemmiscus curtatus*	L	m1		2N 2-3E 70-75 cmbd	
2214	*Lemmiscus curtatus*	L	m1	4T	2N 2-3E 70-75 cmbd	
2215	*Lemmiscus curtatus*	R	m1		2N 2-3E 70-75 cmbd	
2216	*Lemmiscus curtatus*	R	m1		2N 2-3E 70-75 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2217	*Lemmiscus curtatus*	R	dentary with m1		1N 2-3E 75-80 cmbd	partial
2218	*Lemmiscus curtatus*	R	dentary with m1		1N 2-3E 75-80 cmbd	partial
2219	*Lemmiscus curtatus*	L	dentary with i1, m1		1N 2-3E 75-80 cmbd	
2220	*Lemmiscus curtatus*	R	m1		1N 2-3E 75-80 cmbd	
2221	*Lemmiscus curtatus*	L	dentary with m1-2		1N 2-3E 75-80 cmbd	fragment; juvenile
2222	*Lemmiscus curtatus*	R	m1		1N 2-3E 75-80 cmbd	
2223	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	1N 2-3E 75-80 cmbd	
2224	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2225	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2226	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2227	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2228	*Lemmiscus curtatus*	L	dentary with i1, m1		2N 2-3E 75-80 cmbd	posterior loop missing
2229	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2230	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2231	*Lemmiscus curtatus*	L	m1		2N 2-3E 75-80 cmbd	
2232	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2233	*Lemmiscus curtatus*	L	dentary with m1		2N 2-3E 75-80 cmbd	partial
2234	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2235	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2236	*Lemmiscus curtatus*	L	m1		2N 2-3E 75-80 cmbd	
2237	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2238	*Lemmiscus curtatus*	L	m1		2N 2-3E 75-80 cmbd	digested
2239	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	digested
2240	*Lemmiscus curtatus*	L	m1	4T, T5 with incipient closure	2N 2-3E 75-80 cmbd	
2241	*Lemmiscus curtatus*	L	m1		2N 2-3E 75-80 cmbd	digested
2242	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2243	*Lemmiscus curtatus*	R	m1		2N 2-3E 75-80 cmbd	
2244	*Lemmiscus curtatus*	L	m1		1N 2-3E 80-85 cmbd	
2245	*Lemmiscus curtatus*	L	m1		1N 2-3E 80-85 cmbd	
2246	*Lemmiscus curtatus*	L	m1		1N 2-3E 80-85 cmbd	
2247	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2248	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2249	*Lemmiscus curtatus*	R	dentary with m1		2N 2-3E 80-85 cmbd	digested
2250	*Lemmiscus curtatus*	R	dentary with m1-2		2N 2-3E 80-85 cmbd	
2251	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2252	*Lemmiscus curtatus*	R	m1		2N 2-3E 80-85 cmbd	
2253	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2254	*Lemmiscus curtatus*	L	dentary with m1		2N 2-3E 80-85 cmbd	partial
2255	*Lemmiscus curtatus*	R	dentary with m1-2		2N 2-3E 80-85 cmbd	partial
2256	*Lemmiscus curtatus*	R	m1		2N 2-3E 80-85 cmbd	
2257	*Lemmiscus curtatus*	R	m1		2N 2-3E 80-85 cmbd	
2258	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2259	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2260	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	digested?
2261	*Lemmiscus curtatus*	R	m1		2N 2-3E 80-85 cmbd	
2262	*Lemmiscus curtatus*	L	m1		2N 2-3E 80-85 cmbd	
2263	*Lemmiscus curtatus*	R	m1		1N 2-3E 85-90 cmbd	partial
2264	*Lemmiscus curtatus*	L	m1		1N 2-3E 85-90 cmbd	
2265	*Lemmiscus curtatus*	L	m1		1N 2-3E 85-90 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2266	*Lemmiscus curtatus*	R	m1		1N 2-3E 85-90 cmbd	
2267	*Lemmiscus curtatus*	L	m1		1N 2-3E 85-90 cmbd	
2268	*Lemmiscus curtatus*	R	m1		1N 2-3E 85-90 cmbd	
2269	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd	
2270	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd	digested
2271	*Lemmiscus curtatus*	L	m1	T6 pinched	2N 2-3E 85-90 cmbd	
2272	*Lemmiscus curtatus*	L	m1		2N 2-3E 85-90 cmbd	
2273	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd	
2274	*Lemmiscus curtatus*	R	m1	4T	2N 2-3E 85-90 cmbd	
2275	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd	
2276	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd	digested?
2277	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd and below	
2278	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd and below	
2279	*Lemmiscus curtatus*	R	m1		2N 2-3E 85-90 cmbd and below	
1201	*Lemmiscus curtatus*	L	dentary with m1-2		2N 3E 85-110 cmbd below flowstone	
1202	*Lemmiscus curtatus*	R	m1		2N 3E 85-110 cmbd below flowstone	
2280	*Lemmiscus curtatus*	R	m1		2N 3E 85-110 cmbd, below flowstone	digested
2281	*Lemmiscus curtatus*	L	m1	T6 pinched	2N 3E 85-110 cmbd, below flowstone	
2282	*Lemmiscus curtatus*	R	m1		2N 3E 85-110 cmbd, below flowstone	
2283	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	1-2N 2-3E 87-102 cmbd, below rocks	digested
2284	*Lemmiscus curtatus*	L	m1		1-2N 2-3E 87-102 cmbd, below rocks	
2285	*Lemmiscus curtatus*	L	m1		1-2N 2-3E 87-102 cmbd, below rocks	
2286	*Lemmiscus curtatus*	R	m1		2N 2-3E 90-95 cmbd	
2287	*Lemmiscus curtatus*	L	m1		2N 2-3E 90-95 cmbd	
2288	*Lemmiscus curtatus*	R	m1		2N 2-3E 90-95 cmbd	digested?
2289	*Lemmiscus curtatus*	R	m1		2N 2-3E 90-95 cmbd	
2290	*Lemmiscus curtatus*	L	m1		2N 2-3E 90-95 cmbd	
2291	*Lemmiscus curtatus*	L	dentary with m1-2		1N 2-3E 90 cmbd and below	
2292	*Lemmiscus curtatus*	L	m1		1N 2-3E 90 cmbd and below	
2293	*Lemmiscus curtatus*	L	m1		1N 2-3E 90 cmbd and below	
2294	*Lemmiscus curtatus*	L	m1		1N 2-3E 90 cmbd and below	
2295	*Lemmiscus curtatus*	L	m1		2N 2-3E 95-102 cmbd	
2296	*Lemmiscus curtatus*	L	m1		2N 2-3E 95-102 cmbd	
2297	*Lemmiscus curtatus*	R	m1		2N 2-3E 95-102 cmbd	
2298	*Lemmiscus curtatus*	L	m1		2N 2-3E 95-102 cmbd	digested
2299	*Lemmiscus curtatus*	R	m1		2N 3E 100-105 cmbd	
2300	*Lemmiscus curtatus*	R	m1		2N 3E 100-105 cmbd	
2301	*Lemmiscus curtatus*	L	m1		2N 3E 100-105 cmbd	
2302	*Lemmiscus curtatus*	R	m1		2N 3E 100-105 cmbd	
2303	*Lemmiscus curtatus*	L	m1		2N 3E 100-105 cmbd	
2304	*Lemmiscus curtatus*	L	m1		2N 3E 100-105 cmbd	
2305	*Microtus meadensis*	R	m1		2N 3E 40-45 cmbd	
2306	*Microtus meadensis*	?	m1		1N 3E Cemented Level	damaged
2307	*Microtus meadensis*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2308	*Microtus meadensis*	L	m1		2N 2-3E 45-60 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2309	*Microtus meadensis*	R	m1		2N 2-3E 45-60 cmbd	
2310	*Microtus meadensis*	R	m1		2N 2-3E 45-60 cmbd	
2311	*Microtus meadensis*	L	m1		2N 2-3E 45-60 cmbd	
1674	*Microtus meadensis*	R	m1		1N 3E 60-65 cmbd	
2312	*Microtus meadensis*	R	dentary with i1, m1		1N 2E 65-70 cmbd	partial
2313	*Microtus meadensis*	R	m1		1N 2-3E 70-75 cmbd	
2314	*Microtus meadensis*	R	m1		2N 2-3E 70-75 cmbd	
2315	*Microtus meadensis*	R	dentary with m1		2N 2-3E 70-75 cmbd	partial
2316	*Microtus meadensis*	R	m1		2N 2-3E 70-75 cmbd	
2317	*Microtus meadensis*	R	m1		2N 2-3E 75-80 cmbd	
2318	*Microtus meadensis*	L	m1		1N 2-3E 80-85 cmbd	
2319	*Microtus meadensis*	L	m1		2N 2-3E 80-85 cmbd	partial
2320	*Microtus meadensis*	R	m1		2N 2-3E 80-85 cmbd	
2321	*Microtus meadensis*	L	dentary with m1-2		2N 2-3E 90-95 cmbd	
2322	*Microtus meadensis*	L	m1		2N 2-3E 90-95 cmbd	
2323	*Microtus meadensis*	L	m1		2N 2-3E 90-95 cmbd	
2324	*Microtus paroperarius*	R	m1		2N 2E E Half, Upper 50 cm	
2325	*Microtus paroperarius*	L	m1		2N 2E E Half, Upper 50 cm	
2326	*Microtus paroperarius*	L	m1		2N 2-3E 45-75 cmbd; S wall scrapings	
2327	*Microtus paroperarius*	R	m1		1N 2E 30-35 cmbd	
2328	*Microtus paroperarius*	L	m1		1N 2E 30-35 cmbd	
2329	*Microtus paroperarius*	L	m1		1N 2E 35-40 cmbd	
2330	*Microtus paroperarius*	R	m1		2N 3E 40-45 cmbd	
2331	*Microtus paroperarius*	L	m1		2N 3E 40-45 cmbd	
1941	*Microtus paroperarius*	L	m1		2N 3E Cemented Level	
1945	*Microtus paroperarius*	L	m1		2N 3E Cemented Level	
1954	*Microtus paroperarius*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	
2332	*Microtus paroperarius*	R	m1		1N 3E 43.5-55 cmbd; below cemented level	
2333	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2334	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2335	*Microtus paroperarius*	L	m1		2N 2-3E 45-60 cmbd	
2336	*Microtus paroperarius*	L	m1		2N 2-3E 45-60 cmbd	
2337	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2338	*Microtus paroperarius*	L	m1	4T, T5 pinched	2N 2-3E 45-60 cmbd	
2339	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2340	*Microtus paroperarius*	R	m1	4T, T5 pinched	2N 2-3E 45-60 cmbd	
2341	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2342	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2343	*Microtus paroperarius*	R	m1		2N 2-3E 45-60 cmbd	
2344	*Microtus paroperarius*	L	m1	4T, T5 pinched	1N 2E 50-55 cmbd	
2345	*Microtus paroperarius*	L	dentary with m1-2		1N 3E 55-60 cmbd	
2346	*Microtus paroperarius*	R	m1		2N 2-3 E 60-65 cmbd	
2347	*Microtus paroperarius*	R	m1		2N 2-3 E 60-65 cmbd	
2348	*Microtus paroperarius*	L	m1		2N 2-3 E 60-65 cmbd	
2349	*Microtus paroperarius*	L	m1		2N 2-3 E 60-65 cmbd	
2350	*Microtus paroperarius*	L	m1		2N 2-3E 60-65 cmbd	
2351	*Microtus paroperarius*	L	m1		1N 2E 65-70 cmbd	
2352	*Microtus paroperarius*	R	m1		2N 2-3E 65-70 cmbd	
2353	*Microtus paroperarius*				2N 2-3E 65-70 cmbd	
2354	*Microtus paroperarius*				1N 2-3E 70-75 cmbd	
702	*Microtus paroperarius*	R	m1		1N 2-3E 70-75 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2355	*Microtus paroperarius*	R	m1	3T	1N 2-3E 70-75 cmbd	
2356	*Microtus paroperarius*	R	m1		1N 2-3E 70-75 cmbd	
2357	*Microtus paroperarius*	L	m1		2N 2-3E 70-75 cmbd	
2358	*Microtus paroperarius*	L	m1		2N 2-3E 70-75 cmbd	
2359	*Microtus paroperarius*	R	m1		2N 2-3E 70-75 cmbd	
2360	*Microtus paroperarius*	R	m1		2N 2-3E 70-75 cmbd	
2361	*Microtus paroperarius*	R	m1		2N 2-3E 70-75 cmbd	
2362	*Microtus paroperarius*	L	m1		1N 2-3E 75-80 cmbd	
2363	*Microtus paroperarius*	R	m1		2N 2-3E 75-80 cmbd	
2364	*Microtus paroperarius*	R	m1	4T, T5 pinched	2N 2-3E 75-80 cmbd	
2365	*Microtus paroperarius*	R	m1		2N 2-3E 75-80 cmbd	
2366	*Microtus paroperarius*	L	m1		2N 2-3E 75-80 cmbd	
2367	*Microtus paroperarius*	L	m1		2N 2-3E 80-85 cmbd	
2368	*Microtus paroperarius*	R	m1		2N 2-3E 80-85 cmbd	
2369	*Microtus paroperarius*	L	m1		2N 2-3E 80-85 cmbd	
2370	*Microtus paroperarius*	R	dentary w/ m1		2N 2-3E 80-85 cmbd	partial
2371	*Microtus paroperarius*	R	m1		1N 2-3E 85-90 cmbd	
2372	*Microtus paroperarius*	R	m1		2N 2-3E 85-90 cmbd	
2373	*Microtus paroperarius*	L	m1		2N 2-3E 85-90 cmbd	
2374	*Microtus paroperarius*	L	m1		2N 3E 85-110 cmbd, below flowstone	
2375	*Microtus paroperarius*	R	m1		2N 2-3E 90-95 cmbd	
2376	*Microtus sp.*	L	m1	6T	1N 2E No Provenience; under big rock	
2377	*Microtus sp.*	R	m1	5T	1N 2E No Provenience; under big rock	
2378	*Microtus sp.*	R	m1	5T	2N 2E E Half Upper 50 cm	
2379	*Microtus sp.*	R	m1	5T?	2N 2E E Half Upper 50 cm	broken
2380	*Microtus sp.*	R	m1	5T	2N 2E E Half Upper 50 cm	
2381	*Microtus sp.*	L	m1	6T	2N 2E E Half, Upper 50 cm	
2382	*Microtus sp.*	R	m1	5T	1N 2E 25-65 cmbd; wall scrapings	
2383	*Microtus sp.*	L	m1	5T	1N 3E 25-60 cmbd; E wall scrapings	
2384	*Microtus sp.*	L	m1	5T	1N 3E 25-60 cmbd; wall scrapings	
2385	*Microtus sp.*	R	m1	5T	1N 3E 25-60 cmbd; wall scrapings	
2386	*Microtus sp.*	R	m1	5T, T6 pinched	1N 3E 25-60 cmbd; wall scrapings	
2387	*Microtus sp.*	R	m1	5T	2N 3E 40-56 cmbd; NE corner suspect	
2388	*Microtus sp.*	R	m1	5T	2N 3E 40-56 cmbd; NE corner suspect	
2389	*Microtus sp.*	R	m1	5T	2N 3E 40-56 cmbd; NE corner suspect	
2390	*Microtus sp.*	R	m1	5T	1N 3E 45-70 cmbd; wall collapse	
2391	*Microtus sp.*	R	m1	5T	1N 3E 45-70 cmbd; wall collapse	
2392	*Microtus sp.*	L	m1	5T	2N 2-3E 45-75 cmbd; S wall scrapings	
2393	*Microtus sp.*	L	m1	5T	2N 2-3E 45-75 cmbd; S wall scrapings	
2394	*Microtus sp.*	R	partial m1	5T	2N 3E 30-35 cmbd	
2395	*Microtus sp.*	L	m1	5T	1N 2E 35-40 cmbd	juvenile

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2396	*Microtus sp.*	L	partial m1	5T?	1N 3E 35-40 cmbd	
2397	*Microtus sp.*	R	m1	6T	1N 3E 35-40 cmbd	
2398	*Microtus sp.*	R	m1	5T, T6 w/ incipient closure	1N 3E 35-40 cmbd	
2399	*Microtus sp.*	L	m1	5T	1N 3E 35-40 cmbd	
2400	*Microtus sp.*	R	m1	5T	1N 3E 35-40 cmbd	
2401	*Microtus sp.*	R	m1	5T	1N 3E 35-40 cmbd	
2402	*Microtus sp.*	R	m1	5T	2N 3E 35-40 cmbd	
2403	*Microtus sp.*	L	m1	5T	1N 3E 40-45 cmbd	
2404	*Microtus sp.*	R	partial m1	5T?	2N 3E 40-45 cmbd	
2405	*Microtus sp.*	L	m1	5T	2N 3E 40-45 cmbd	
2406	*Microtus sp.*	L	m1	6T	2N 3E 40-45 cmbd	
2407	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2408	*Microtus sp.*	L	m1	5T	2N 3E 40-45 cmbd	
2409	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2410	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2411	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	digested
2412	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2413	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2414	*Microtus sp.*	R	m1	5T	2N 3E 40-45 cmbd	
2415	*Microtus sp.*	L	m1	5T?	1N 3E Cemented Level	broken
2416	*Microtus sp.*	L	m1	5T, T6/7 pinched	1N 3E Cemented Level	
2417	*Microtus sp.*	L	m1	5T	1N 3E Cemented Level	
2418	*Microtus sp.*	R	m1	6T	1N 3E Cemented Level	
2419	*Microtus sp.*	R	m1	5T	1N 3E Cemented Level	
2420	*Microtus sp.*	R	m1	5T	2N 3E Cemented Level	
2421	*Microtus sp.*	R	partial dentary with i1, m1	5T	2N 3E Cemented Level	
2422	*Microtus sp.*	R	m1	6T	2N 3E Cemented Level	
2423	*Microtus sp.*	R	m1	5T	2N 3E Cemented Level	
2424	*Microtus sp.*	R	m1	5T	2N 3E Cemented Level	
2425	*Microtus sp.*	R	m1	5T	2N 3E Cemented Level	
2426	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2E E Half Cemented Level	
2427	*Microtus sp.*	L	m1	5T	1N 3E 43.5-55 cmbd, below cemented level	digested?
2428	*Microtus sp.*	R	dentary with m1-m2	5T	1N 3E 43.5-55 cmbd, below cemented level	partial
2429	*Microtus sp.*	R	m1	5T	1N 3E 43.5-55 cmbd, below cemented level	
2430	*Microtus sp.*	L	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2431	*Microtus sp.*	R	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2432	*Microtus sp.*	L	m1	6T	1N 3E 43.5-55 cmbd; below cemented level	
2433	*Microtus sp.*	R	m1	5T, closed cap	1N 3E 43.5-55 cmbd; below cemented level	
2434	*Microtus sp.*	L	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2435	*Microtus sp.*	L	partial m1	5T?	1N 3E 43.5-55 cmbd; below cemented level	
2436	*Microtus sp.*	L	partial m1	5T?	1N 3E 43.5-55 cmbd; below cemented level	
2437	*Microtus sp.*	L	partial dentary with m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2438	*Microtus sp.*	L	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2439	*Microtus sp.*	L	m1	5T, T6 pinched	1N 3E 43.5-55 cmbd; below cemented level	
2440	*Microtus sp.*	R	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2441	*Microtus sp.*	R	partial m1	preservation	1N 3E 43.5-55 cmbd; below cemented level	
2442	*Microtus sp.*	R	m1	5T	1N 3E 43.5-55 cmbd; below cemented level	
2443	*Microtus sp.*	L	m1	5T, T6 pinched	1N 2E 45-50 cmbd	
2444	*Microtus sp.*	R	m1	5T	1N 2E 45-50 cmbd	
2445	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2446	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2447	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2448	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	digested?
2449	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2450	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2451	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2452	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2453	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2454	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2455	*Microtus sp.*	L	m1	5T, no T7; hooked anterior cap	2N 2-3E 45-60 cmbd	
2456	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2-3E 45-60 cmbd	
2457	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2458	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2459	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2460	*Microtus sp.*	L	dentary with m1	5T	2N 2-3E 45-60 cmbd	
2461	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2462	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2463	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2464	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 45-60 cmbd	
2465	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2466	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2467	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2468	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2469	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2470	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2471	*Microtus sp.*	R	dentary with i1, m1-2	5T, T6 pinched	2N 2-3E 45-60 cmbd	
2472	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2473	*Microtus sp.*	L	m1	5T, T7 weakly developed	2N 2-3E 45-60 cmbd	
2474	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	digested?
2475	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2476	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2477	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	digested?
2478	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2479	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2480	*Microtus sp.*	R	m1	6T	2N 2-3E 45-60 cmbd	
2481	*Microtus sp.*	R	m1	preservation	2N 2-3E 45-60 cmbd	
2482	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	digested
2483	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	aberrant cap morph.
2484	*Microtus sp.*	R	m1	5T, T7 weakly developed	2N 2-3E 45-60 cmbd	
2485	*Microtus sp.*	R	dentary with m1-2	5T	2N 2-3E 45-60 cmbd	
2486	*Microtus sp.*	L	m1	5T, T6 with incipient closure	2N 2-3E 45-60 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2487	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2488	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2489	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2490	*Microtus sp.*	R	m1	6T	2N 2-3E 45-60 cmbd	
2491	*Microtus sp.*	L	Partial dentary with i1, m1-m2	5T	2N 2-3E 45-60 cmbd	
2492	*Microtus sp.*	R	m1	5T	2N 2-3E 45-60 cmbd	
2493	*Microtus sp.*	L	m1	5T	2N 2-3E 45-60 cmbd	
2494	*Microtus sp.*	L	m1	5T	1N 2E 50-55 cmbd	
2495	*Microtus sp.*	L	m1	5T	1N 2E 50-55 cmbd	partial
2496	*Microtus sp.*	L	m1	5T?	1N 2E 50-55 cmbd	partial
2497	*Microtus sp.*	R	m1	5T, T6 w/ incipient closure	1N 2E 50-55 cmbd	
2498	*Microtus sp.*	L	m1	5T	1N 2E 50-55 cmbd	
2499	*Microtus sp.*	L	m1	5T	1N 2E 50-55 cmbd	
2500	*Microtus sp.*	L	m1	5T	1N 2E 50-55 cmbd	digested
2501	*Microtus sp.*	R	m1	5T	1N 2E 55-60 cmbd	
2502	*Microtus sp.*	R	m1	5T	1N 2E 55-60 cmbd	
2503	*Microtus sp.*	L	m1	5T, T6 w/ incipient closure	1N 2E 55-60 cmbd	
2504	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2505	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2506	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	T7 weakly developed
2507	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	secondary wings pinched from cap
2508	*Microtus sp.*	R	m1	5T	1N 3E 55-60 cmbd	
2509	*Microtus sp.*	L	m1	5T?	1N 3E 55-60 cmbd	partial
2510	*Microtus sp.*	L	dentary with m1-2	5T	1N 3E 55-60 cmbd	partial
2511	*Microtus sp.*	L	Dentary with m1-2	5T	1N 3E 55-60 cmbd	Partial
2512	*Microtus sp.*	R	m1	6T	1N 3E 55-60 cmbd	Aberrant
2513	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2514	*Microtus sp.*	R	m1	5T	1N 3E 55-60 cmbd	
2515	*Microtus sp.*	R	m1	5T	1N 3E 55-60 cmbd	
2516	*Microtus sp.*	L	dentary with i1, m1-2	5T	1N 3E 55-60 cmbd	
2517	*Microtus sp.*	R	m1	5T	1N 3E 55-60 cmbd	
2518	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2519	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2520	*Microtus sp.*	L	m1	5T	1N 3E 55-60 cmbd	
2521	*Microtus sp.*	L	dentary with i1, m1	T1/T2 confluent	1N 3E 55-60 cmbd	partial
2522	*Microtus sp.*	R	m1	5T	1N 2E 60-65 cmbd	
2523	*Microtus sp.*	L	m1	5T	1N 2E 60-65 cmbd	
2524	*Microtus sp.*	L	m1	5T	1N 2E 60-65 cmbd	
2525	*Microtus sp.*	R	m1	5T	1N 2E 60-65 cmbd	
2526	*Microtus sp.*	R	m1	5T	1N 2E 60-65 cmbd	
2527	*Microtus sp.*	R	m1	6T	1N 2E 60-65 cmbd	
2528	*Microtus sp.*	L	m1	5T	1N 2E 60-65 cmbd	
2529	*Microtus sp.*	L	m1	6T	1N 2E 60-65 cmbd	digested
2530	*Microtus sp.*	L	m1	5T	1N 2E 60-65 cmbd	
2531	*Microtus sp.*	L	m1	T6 w/ incipient closure	1N 2E 60-65 cmbd	digested
2532	*Microtus sp.*	L	m1	5T	1N 2E 60-65 cmbd	
2533	*Microtus sp.*	R	m1	5T	1N 2E 60-65 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2534	*Microtus sp.*	L	m1	5T	1N 3E 60-65 cmbd	
2535	*Microtus sp.*	L	m1	6T	1N 3E 60-65 cmbd	
2536	*Microtus sp.*	R	m1	5T	1N 3E 60-65 cmbd	
2537	*Microtus sp.*	R	m1	5T	2N 2-3 E 60-65 cmbd	
2538	*Microtus sp.*	L	m1	5T	2N 2-3 E 60-65 cmbd	
2539	*Microtus sp.*	L	m1	5T	2N 2-3 E 60-65 cmbd	
2540	*Microtus sp.*	R	m1	5T	2N 2-3 E 60-65 cmbd	
2541	*Microtus sp.*	R	dentary with m1-2	5T	2N 2-3 E 60-65 cmbd	digested
2542	*Microtus sp.*	L	dentary with m1-2	5T	2N 2-3 E 60-65 cmbd	
2543	*Microtus sp.*	L	m1	5T	2N 2-3 E 60-65 cmbd	
2544	*Microtus sp.*	L	m1	5T	2N 2-3 E 60-65 cmbd	
2545	*Microtus sp.*	R	m1	5T	2N 2-3 E 60-65 cmbd	
2546	*Microtus sp.*	R	m1	5T, T6 with incipient closure	2N 2-3 E 60-65 cmbd	
2547	*Microtus sp.*	R	m1	5T	2N 2-3 E 60-65 cmbd	
2548	*Microtus sp.*	R	m1	5T	2N 2-3E 60-65 cmbd	
1466	*Microtus sp.*	L	m1	5T	1N 3E 65-70 cmbd	
2549	*Microtus sp.*	L	m1	6T	1N 2E 65-70 cmbd	digested?
2550	*Microtus sp.*	R	m1	5T	1N 2E 65-70 cmbd	
2551	*Microtus sp.*	L	m1	5T	1N 2E 65-70 cmbd	
2552	*Microtus sp.*	R	m1	6T, weakly-developed T7	1N 2E 65-70 cmbd	
2553	*Microtus sp.*	R	m1	5T	1N 2E 65-70 cmbd	
2554	*Microtus sp.*	L	m1	6T	1N 2E 65-70 cmbd	
2555	*Microtus sp.*	L	m1	5T	1N 2E 65-70 cmbd	
2556	*Microtus sp.*	L	m1	5T	1N 2E 65-70 cmbd	
2557	*Microtus sp.*	L	m1	5T	1N 2E 65-70 cmbd	
2558	*Microtus sp.*	L	m1	5T	1N 3E 65-70 cmbd	
2559	*Microtus sp.*	L	dentary with i1, m1-2	5T	1N 3E 65-70 cmbd	partial
2560	*Microtus sp.*	L	m1	5T	1N 3E 65-70 cmbd	digested
2561	*Microtus sp.*	R	m1	5T, T6 with incipient closure	2N 2-3E 65-70 cmbd	
2562	*Microtus sp.*	R	m1	5T	2N 2-3E 65-70 cmbd	
2563	*Microtus sp.*	L	m1	5T	2N 2-3E 65-70 cmbd	
2564	*Microtus sp.*	L	m1	5T	2N 2-3E 65-70 cmbd	
2565	*Microtus sp.*	L	m1	5T	2N 2-3E 65-70 cmbd	digested
2566	*Microtus sp.*	R	dentary with i1, m1	5T	2N 2-3E 65-70 cmbd	
2567	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 65-70 cmbd	
2568	*Microtus sp.*	L	m1	5T, weak secondary wings	2N 2-3E 65-70 cmbd	
2569	*Microtus sp.*	R	dentary with m1-2	5T	2N 2-3E 65-70 cmbd	
2570	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 65-70 cmbd	digested
2571	*Microtus sp.*	L	m1	5T, T6 with incipient closure	2N 2-3E 65-70 cmbd	
2572	*Microtus sp.*	R	m1	5T	2N 2-3E 65-70 cmbd	
2573	*Microtus sp.*	R	m1	5T	2N 2-3E 65-70 cmbd	
2574	*Microtus sp.*	R	m1	5T, T6 with incipient closure	2N 2-3E 65-70 cmbd	
2575	*Microtus sp.*	L	m1	5T	2N 2-3E 65-70 cmbd	digested
2576	*Microtus sp.*	R	m1	5T	2N 2-3E 65-70 cmbd	
715	*Microtus sp.*	R	m1	6T	1N 2-3E 70-75 cmbd	
722	*Microtus sp.*	L	m1	5T	1N 2-3E 70-75 cmbd	
756	*Microtus sp.*	R	m1	7T	1N 2-3E 70-75 cmbd	partial
2577	*Microtus sp.*	L	m1	5T	1N 2-3E 70-75 cmbd	
2578	*Microtus sp.*	L	m1	5T	1N 2-3E 70-75 cmbd	digested

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2579	*Microtus sp.*	L	m1	5T	1N 2-3E 70-75 cmbd	
2580	*Microtus sp.*	R	m1	5T	1N 2-3E 70-75 cmbd	
2581	*Microtus sp.*	L	m1	5T	1N 2-3E 70-75 cmbd	
2582	*Microtus sp.*	L	m1	6T	1N 2-3E 70-75 cmbd	
2583	*Microtus sp.*	R	m1	5T	1N 2-3E 70-75 cmbd	
2584	*Microtus sp.*	L	m1	5T, T6 pinched	1N 2-3E 70-75 cmbd	
2585	*Microtus sp.*	R	m1	5T	1N 2-3E 70-75 cmbd	digested
2586	*Microtus sp.*	R	m1	5T	1N 2-3E 70-75 cmbd	
2587	*Microtus sp.*	R	m1	5T	1N 2-3E 70-75 cmbd	
2588	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2589	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2590	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2591	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2592	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2593	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2-3E 70-75 cmbd	
2594	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2595	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	digested
2596	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2597	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2598	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2599	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2600	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2601	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2602	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2603	*Microtus sp.*	L	m1	6T	2N 2-3E 70-75 cmbd	
2604	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2-3E 70-75 cmbd	
2605	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2606	*Microtus sp.*	R	m1	5T	2N 2-3E 70-75 cmbd	
2607	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2608	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 70-75 cmbd	
2609	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2610	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	
2611	*Microtus sp.*	L	m1	5T	2N 2-3E 70-75 cmbd	digested
2612	*Microtus sp.*	L	m1	5T, T6 pinched	1N 2-3E 75-80 cmbd	
2613	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	
2614	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	
2615	*Microtus sp.*	L	dentary with m1	5T	1N 2-3E 75-80 cmbd	digested
2616	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	digested?
2617	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	
2618	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	digested
2619	*Microtus sp.*	R	m1	5T	1N 2-3E 75-80 cmbd	digested
2620	*Microtus sp.*	L	m1	6T	2N 2-3E 75-80 cmbd	
2621	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2622	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 75-80 cmbd	
2623	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2624	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2625	*Microtus sp.*	L	m1	6T	2N 2-3E 75-80 cmbd	digested
2626	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2627	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2628	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2-3E 75-80 cmbd	digested?
2629	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2630	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2631	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2632	*Microtus sp.*	L	m1	5T, T6 with incipient closure	2N 2-3E 75-80 cmbd	
2633	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	digested
2634	*Microtus sp.*	L	m1	5T, T6 pinched	2N 2-3E 75-80 cmbd	digested
2635	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2636	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2637	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2638	*Microtus sp.*	L	dentary with i1, m1-2	5T, T6 with incipient closure	2N 2-3E 75-80 cmbd	
2639	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 75-80 cmbd	digested?
2640	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2641	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2642	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2643	*Microtus sp.*	L	m1	5T	2N 2-3E 75-80 cmbd	
2644	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 75-80 cmbd	
2645	*Microtus sp.*	R	m1	6T	2N 2-3E 75-80 cmbd	
2646	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	digested
2647	*Microtus sp.*	R	m1	5T	2N 2-3E 75-80 cmbd	
2648	*Microtus sp.*	R	m1	6T	1N 2-3E 80-85 cmbd	
2649	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	
2650	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	
2651	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	digested
2652	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	
2653	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	
2654	*Microtus sp.*	R	m1	5T, T6 pinched	2N 2-3E 80-85 cmbd	
2655	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	digested
2656	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	
2657	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	
2658	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	
2659	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	
2660	*Microtus sp.*	L	m1	5T?	2N 2-3E 80-85 cmbd	
2661	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	digested
2662	*Microtus sp.*	L	m1	5T	2N 2-3E 80-85 cmbd	juvenile
2663	*Microtus sp.*	R	m1	5T	2N 2-3E 80-85 cmbd	digested
2664	*Microtus sp.*	L	m1	5T	1N 2-3E 85-90 cmbd	digested
2665	*Microtus sp.*	R	m1	5T	1N 2-3E 85-90 cmbd	digested
1200	*Microtus sp.*	R	m1	5T	2N 3E 85-110 cmbd below flowstone	
2666	*Microtus sp.*	R	m1	5T	2N 2-3E 85-90 cmbd and below	
2667	*Microtus sp.*	L	m1	5T	2N 2-3E 85-90 cmbd and below	
2668	*Microtus sp.*	L	dentary with i1, m1	5T, T6 pinched	2N 2-3E 90-95 cmbd	
582	*Microtus sp.*	R	m1	5T	2N 2-3E 90-95 cmbd	
2670	*Microtus sp.*	L	m1	5T	2N 2-3E 90-95 cmbd	partial
2671	*Microtus sp.*	L	dentary with m1	5T	2N 2-3E 90-95 cmbd	
2672	*Microtus sp.*	L	m1	5T	2N 2-3E 90-95 cmbd	digested
2673	*Microtus sp.*	R	m1	5T	1N 2-3E 90 cmbd and below	
2674	*Microtus sp.*	L	m1	5T	1N 2-3E 90 cmbd and below	
2675	*Microtus sp.*	R	m1	5T	1N 2-3E 90 cmbd and below	
2676	*Microtus sp.*	L	m1	5T, T6 with incipient closure	1N 2-3E 90 cmbd and below	
2677	*Microtus sp.*	R	dentary with m1	5T, T6 pinched	1N 2-3E 90 cmbd and below	fragment
2678	*Microtus sp.*	R	dentary with i1, m1-2	5T	1N 2-3E 90 cmbd and below	
2679	*Microtus sp.*	R	m1	5T	1N 2-3E 90 cmbd and below	
2680	*Microtus sp.*	L	m1	5T	1N 2-3E 90 cmbd and below	

Appendix 5 continued.

#	Taxon	S	Element	Morphotype	Provenience	Comments
2681	*Microtus sp.*	R	m1	5T	1N 2-3E 90 cmbd and below	
2682	*Microtus sp.*	R	m1	5T? or meadensis	2N 3E 100-105 cmbd	digested
2683	*Microtus sp.*	R	m1	5T	2N 3E 100-105 cmbd	digested
2684	*Microtus sp.*	L	m1	5T	2N 3E 100-105 cmbd	digested
2685	*Microtus sp.*	R	m1	5T	2N 3E 100-105 cmbd	
2686	*Mictomys meltoni or M. kansensis*	L	m1		1N 2E 30-35 cmbd	
1933	*Mictomys meltoni or M. kansensis*	R	m1		1N 3E Cemented Level	
2687	*Mictomys meltoni or M. kansensis*	L	m1		1N 2-3E 70-75 cmbd	
2688	*Mictomys meltoni or M. kansensis*	R	m1		2N 2-3E 70-75 cmbd	
2689	*Mictomys meltoni or M. kansensis*	L	m1		2N 2-3E 70-75 cmbd	
2690	*Mictomys sp.*	L	m1	preservation	1N 2E 50-55 cmbd	digested
2691	*Ondatra zibethicus*	L	m1		1N 3E 55-60 cmbd	
2692	*Ondatra zibethicus*	R	m1		1N 2-3E 90 cmbd and below	
2693	*Ondatra sp.*	R	M2		2N 2-3E 45-60 cmbd	
2694	*Phenacomys* cf. *P. gryci*	R	dentary with m1	4T, kante absent	1N 3E 30-35 cmbd	
234	*Phenacomys* cf. *P. gryci*	R	m1	4T, kante present	2N 2-3E 45-60 cmbd	
2695	*Phenacomys* cf. *P. gryci*	R	dentary with m1-2	3T, kante present	2N 2-3E 45-60 cmbd	partial
2696	*Phenacomys* cf. *P. gryci*	R	dentary with m1	3T, kante present	2N 2-3E 45-60 cmbd	partial
2697	*Phenacomys* cf. *P. gryci*	L	dentary with i1, m1	3T, kante present	2N 2-3E 45-60 cmbd	juvenile?
2698	*Phenacomys* cf. *P. gryci*	R	m1	3T, T4 w/incipient closure; kante present	2N 2-3E 45-60 cmbd	
2699	*Phenacomys* cf. *P. gryci*	L	m1	3T, T4 pinched; kante present	2N 2-3E 45-60 cmbd	
2700	*Phenacomys* cf. *P. gryci*	L	m1	4T, kante absent	2N 2-3E 45-60 cmbd	
2701	*Phenacomys* cf. *P. gryci*	R	m1	3T; kante present	2N 2-3E 45-60 cmbd	
2702	*Phenacomys* cf. *P. gryci*	R	m1	5T, kante present	1N 3E 55-60 cmbd	T5 closed
2703	*Phenacomys* cf. *P. gryci*	L	m1	4T; kante present	1N 2E 60-65 cmbd	
2704	*Phenacomys* cf. *P. gryci*	R	m1	3T, T4 w/ incipient closure; kante absent	1N 3E 60-65 cmbd	
2705	*Phenacomys* cf. *P. gryci*	R	m1	5T; kante present	1N 3E 60-65 cmbd	
2706	*Phenacomys* cf. *P. gryci*	R	m1	3T, T4 w/ incipient closure; kante present	2N 2-3 E 60-65 cmbd	
2707	*Phenacomys* cf. *P. gryci*	L	dentary with m1-m2	4T; kante present	1N 2E 65-70 cmbd	partial
2708	*Phenacomys* cf. *P. gryci*	R	dentary with i1, m1-2	4T, T5 pinched, kante present	1N 3E 65-70 cmbd	partial
2709	*Phenacomys* cf. *P. gryci*	R	m1	3T, T4 w/ incipient closure; kante present	2N 2-3E 65-70 cmbd	
2710	*Phenacomys* cf. *P. gryci*	L	m1	4T, kante present	2N 2-3E 65-70 cmbd	
728	*Phenacomys* cf. *P. gryci*	L	dentary with m1	3T, T4 pinched; kante present	1N 2-3E 70-75 cmbd	partial
2711	*Phenacomys* cf. *P. gryci*	R	m1	5T; kante absent	2N 2-3E 70-75 cmbd	
2712	*Phenacomys* cf. *P. gryci*	L	m1	4T; kante present	2N 2-3E 70-75 cmbd	heavily worn
2713	*Phenacomys* cf. *P. gryci*	R	dentary with i1, m1	4T, kante present	2N 2-3E 70-75 cmbd	
2714	*Phenacomys* cf. *P. gryci*	L	m1	3T, T4 w/ incipient closure; kante absent	2N 2-3E 70-75 cmbd	

Appendix 5 continued.

2715	*Phenacomys* cf. *P. gryci*	R	m1	4T, kante present	2N 2-3E 70-75 cmbd	
2716	*Phenacomys* cf. *P. gryci*	L	m1	5T; kante absent	2N 2-3E 70-75 cmbd	
2717	*Phenacomys* cf. *P. gryci*	L	m1	4T, kante present	2N 2-3E 75-80 cmbd	
2718	*Phenacomys* cf. *P. gryci*	L	m1	4T; kante absent	2N 2-3E 75-80 cmbd	
2719	*Phenacomys* cf. *P. gryci*	L	m1	3T, T4 w/ incipient closure; kante present	2N 2-3E 75-80 cmbd	cleaned with 10% acetic acid
2720	*Phenacomys* cf. *P. gryci*	L	dentary with i1, m1	3T, T4 pinched; kante present	2N 2-3E 80-85 cmbd	
2721	*Phenacomys* cf. *P. gryci*	L	m1	4T; kante present	2N 2-3E 85-90 cmbd	
2722	*Phenacomys* cf. *P. gryci*	L	m1	3T, T4 pinched; kante present	1N 2-3E 90 cmbd and below	
2723	*Phenacomys sp.*	L	m1		1N 3E Cemented Level	(not gryci)
2724	*Phenacomys sp.*	R	dentary with m1-m2		1N 3E Cemented Level	partial; (not gryci)
2725	*Phenacomys sp.*	L	partial m1		2N 3E Cemented Level	
2726	*Phenacomys sp.*	L	m1		1N 2E 45-50 cmbd	(not gryci)
2727	*Phenacomys sp.*	R	m1		2N 2-3E 45-60 cmbd	(not gryci)
2728	*Phenacomys sp.*	R	m1		1N 3E 55-60 cmbd	partial; (not gryci)
2729	*Phenacomys gryci or Mimomys*	L	partial dentary with m1-m3		1N 3E 43.5-55 cmbd; below cemented level	
2730	*?Phenacomys?*	L	m1		1N 3E 43.5-55 cmbd; below cemented level	partial
2731	*?Lemmiscus sp.?*	R	dentary w/ i/1, m1-m2	4T	1N 2E 65-70 cmbd	
2732	*?Microtus meadensis?*	R	m1		2N 2-3E 80-85 cmbd	

APPENDIX 6. COMPLETE LIST OF IDENTIFIED ARVICOLINE RODENTS FROM SMITH CREEK CAVE.

S.N. = Specimen Number. Individual specimen numbers are preceded in the text by the acronym SCCAR-; citation of individual specimens should include this acronym. Abbreviations for stratigraphic units (Strat.Unit) are as follows: R/P Silt = reddish/pink Silt; RD/BS = rodent dung and brown silt layer; U/Q = unknown or questionable provenience. There is no specimen assigned SCCAR-116 because the specimen originally allocated that number was discovered to be from a different locality and was excluded from this report.

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
1	*Microtus* sp.	R	m1	5T	R/P Silt	
2	*Microtus* sp.	L	Partial dentary with i1, m1	5T, T1-T2 confluent	R/P Silt	
3	*Microtus* sp.	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
4	*Microtus* sp.	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
5	*Microtus* sp.	R	m1	5T	R/P Silt	
6	*Microtus* sp.	R	m1	5T	R/P Silt	
7	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
8	*Microtus* sp.	R	m1	5T	R/P Silt	
9	*Microtus* sp.	R	m1	5T, T6 pinched	R/P Silt	
10	*Microtus* sp.	R	m1	5T	R/P Silt	
11	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
12	*Microtus* sp.	L	m1	5T	R/P Silt	
13	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
14	*Microtus* sp.	L	m1	5T	R/P Silt	
15	*Microtus* sp.	R	Dentary with i1, m1-m2	5T	R/P Silt	
16	*Microtus* sp.	L	m1	5T, T6/T7 w/ incipient closure	R/P Silt	
17	*Microtus* sp.	R	m1	5T	R/P Silt	
18	*Microtus* sp.	R	m1	5T	R/P Silt	
19	*Microtus* sp.	L	Partial dentary with m1-m2	5T	R/P Silt	
20	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
21	*Microtus* sp.	L	Partial dentary with m1-m2	5T	R/P Silt	
22	*Microtus* sp.	R	m1	5T	R/P Silt	
23	*Microtus* sp.	R	m1	5T	R/P Silt	
24	*Microtus* sp.	L	m1	5T	R/P Silt	
25	*Microtus paroperarius*	R	m1	-	R/P Silt	
26	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	RD/BS	
27	*Microtus meadensis*	L	m1	-	RD/BS	
28	*Microtus sp.*	L	m1	5T	RD/BS	
29	*Microtus sp.*	R	m1	5T	RD/BS	
30	*Microtus sp.*	R	m1	6T	RD/BS	
31	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
32	*Microtus sp.*	L	m1	5T	R/P Silt	
33	*Microtus sp.*	R	m1	5T, T6 pinched	R/P Silt	
34	*Microtus sp.*	R	m1	5T, T6 pinched	R/P Silt	digested
35	*Microtus sp.*	R	m1	5T	R/P Silt	
36	*Microtus sp.*	R	m1	5T	R/P Silt	

Appendix 6 continued.

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
37	*Microtus sp.*	R	m1	5T	R/P Silt	
38	*Microtus sp.*	L	m1	5T	R/P Silt	
39	*Microtus sp.*	L	m1	5T	R/P Silt	
40	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
41	*Microtus sp.*	R	m1	5T	R/P Silt	
42	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
43	*Microtus sp.*	R	m1	5T	R/P Silt	
44	*Microtus meadensis*	R	m1	-	R/P Silt	
45	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
46	*Microtus sp.*	R	m1	5T	R/P Silt	
47	*Microtus sp.*	L	m1	5T	R/P Silt	digested
48	*Microtus sp.*	L	Partial dentary with i1, m1-m2	5T	U/Q	
49	*Microtus sp.*	L	Dentary with i1, m1-m3	5T	R/P Silt	
50	*Microtus sp.*	R	m1	5T	R/P Silt	
51	*Microtus sp.*	R	m1	5T	R/P Silt	
52	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
53	*Microtus sp.*	R	m1	5T, T6 w/ incipient closure	R/P Silt	
54	*Microtus sp.*	R	m1	5T	R/P Silt	
55	*Microtus sp.*	L	m1	5T	R/P Silt	
56	*Microtus sp.*	L	m1	5T	R/P Silt	
57	*Microtus sp.*	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
58	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
59	*Lemmiscus curtatus*	R	Dentary with m1-m2	5T	R/P Silt	
60	*Microtus sp.*	L	m1	5T	R/P Silt	
61	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
62	*Microtus sp.*	R	m1	5T, T6 pinched	R/P Silt	
63	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
64	*Microtus paroperarius*	L	m1	-	R/P Silt	
65	*Microtus sp.*	R	m1	5T	R/P Silt	
66	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
67	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
68	*Microtus sp.*	L	m1	5T	R/P Silt	
69	*Microtus sp.*	R	m1	5T, T6 w/ incipient closure	R/P Silt	
70	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
71	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
72	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
73	*Microtus sp.*	R	m1	5T	R/P Silt	
74	*Microtus sp.*	R	m1	5T	R/P Silt	
75	*Microtus sp.*	L	m1	5T	R/P Silt	
76	*Microtus sp.*	R	m1	5T, T6 pinched	R/P Silt	
77	*Microtus sp.*	L	m1	5T	R/P Silt	
78	*Microtus sp.*	R	m1	5T	R/P Silt	
79	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
80	*Microtus sp.*	R	m1	5T	R/P Silt	
81	*Microtus sp.*	L	m1	5T	R/P Silt	
82	*Microtus sp.*	R	m1	5T	R/P Silt	
83	*Microtus sp.*	L	m1	5T	R/P Silt	
84	*Microtus sp.*	L	m1	5T	R/P Silt	
85	*Microtus sp.*	R	m1	6T	R/P Silt	
86	*Microtus sp.*	R	m1	5T	R/P Silt	
87	*Microtus sp.*	L	m1	5T	R/P Silt	

Appendix 6 continued.

S.N.	*Taxon*	Side	Element	Morphotype	Strat. Unit	Misc.
88	*Microtus sp.*	R	m1	5T	R/P Silt	
89	*Microtus sp.*	L	m1	5T	R/P Silt	
90	*Microtus sp.*	L	m1	5T	R/P Silt	
91	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	R/P Silt	
92	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
93	*Microtus sp.*	R	m1	5T	R/P Silt	
94	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
95	*Lemmiscus curtatus*	R	Partial dentary with m1	5T	R/P Silt	
96	*Microtus sp.*	R	m1	5T	R/P Silt	
97	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
98	*Microtus sp.*	R	m1	5T, T6 pinched	R/P Silt	
99	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
100	*Microtus sp.*	L	m1	5T	R/P Silt	
101	*Microtus sp.*	L	m1	5T	R/P Silt	
102	*Microtus sp.*	R	m1	5T	R/P Silt	
103	*Microtus sp.*	R	m1	5T	R/P Silt	
104	*Microtus sp.*	R	m1	5T	R/P Silt	
105	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
106	*Lemmiscus curtatus*	R	m1	4T, T5 pinched	R/P Silt	
107	*Microtus sp.*	R	Dentary with i1, m1-m2	5T	R/P Silt	
108	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	R/P Silt	
109	*Microtus sp.*	L	m1	5T	R/P Silt	
110	*Microtus sp.*	L	m1	5T	R/P Silt	
111	*Microtus sp.*	R	m1	5T	R/P Silt	
112	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
113	*Microtus sp.*	L	Dentary with i1, m1	5T	R/P Silt	
114	*Microtus sp.*	L	m1	5T	R/P Silt	
115	*Microtus sp.*	R	m1	5T	U/Q	
117	*Microtus sp.*	R	Dentary with i1, m1-m3	5T	R/P Silt	
118	*Lemmiscus curtatus*	R	m1	4T	R/P Silt	
119	*Microtus sp.*	L	m1	5T	R/P Silt	
120	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
121	*Microtus sp.*	R	m1	5T	R/P Silt	
122	*Microtus sp.*	R	m1	5T	R/P Silt	
123	*Microtus sp.*	L	m1	5T	R/P Silt	
124	*Microtus sp.*	L	m1	5T	R/P Silt	
125	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
126	*Microtus sp.*	L	m1	5T	R/P Silt	
127	*Lemmiscus curtatus*	L	Dentary with i1, m1	5T	R/P Silt	
128	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
129	*Lemmiscus curtatus*	R	m1	4T	R/P Silt	
130	*Microtus sp.*	L	m1	5T	R/P Silt	
131	*Microtus sp.*	L	m1	5T	R/P Silt	
132	*Microtus sp.*	L	m1	5T	R/P Silt	
133	*Microtus sp.*	R	m1	6T	R/P Silt	
134	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	R/P Silt	
135	*Lemmiscus curtatus*	L	Partial dentary with i1, m1-m2	5T	R/P Silt	
136	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
137	*Microtus sp.*	R	Partial dentary with m1-m2	5T	R/P Silt	

Appendix 6 continued.

S.N.	*Taxon*	Side	Element	Morphotype	Strat. Unit	Misc.
138	*Microtus sp.*	R	Dentary with i1 (fragment), m1-m2	5T	R/P Silt	
139	*Microtus sp.*	L	m1	5T	R/P Silt	
140	*Microtus sp.*	R	m1	6T	R/P Silt	
141	*Microtus sp.*	R	m1	5T	R/P Silt	
142	*Microtus sp.*	L	m1	6T	R/P Silt	
143	*Microtus sp.*	R	m1	5T	R/P Silt	
144	*Microtus sp.*	L	m1	5T	R/P Silt	
145	*Microtus sp.*	L	m1	5T	R/P Silt	
146	*Microtus sp.*	R	m1	5T, T6/T7 closed	R/P Silt	
147	*Microtus sp.*	R	m1	5T	R/P Silt	
148	*Microtus sp.*	L	m1	5T	R/P Silt	
149	*Microtus sp.*	R	m1	5T	R/P Silt	
150	*Microtus sp.*	L	m1	5T	R/P Silt	
151	*Microtus sp.*	L	m1	5T, T6 pinched from T7; T7 closed from cap	R/P Silt	
152	*Microtus sp.*	L	m1	5T	R/P Silt	
153	*Microtus sp.*	R	m1	5T	R/P Silt	
154	*Microtus sp.*	R	m1	5T	R/P Silt	
155	*Microtus sp.*	R	m1	5T	R/P Silt	
156	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
157	*Microtus sp.*	R	m1	5T	R/P Silt	
158	*Microtus sp.*	R	m1	5T	R/P Silt	
159	*Microtus sp.*	R	m1	5T	R/P Silt	
160	*Microtus sp.*	R	m1	5T	R/P Silt	
161	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
162	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
163	*Microtus sp.*	R	m1	5T	R/P Silt	
164	*Lemmiscus curtatus*	L	m1	4T, T5 pinched	R/P Silt	
165	*Microtus sp.*	L	Partial dentary with m1-m2	5T, T6 pinched	R/P Silt	
166	*Microtus sp.*	L	m1	5T, T6/T7 pinched from cap	R/P Silt	
167	*Microtus sp.*	R	m1	5T	R/P Silt	
168	*Microtus sp.*	R	m1	5T	R/P Silt	
169	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	U/Q	
170	*Microtus sp.*	L	Partial dentary with i1, m1-m2	5T, T6 pinched	U/Q	
171	*Microtus sp.*	R	m1	5T	U/Q	
172	*Microtus sp.*	L	m1	6T	U/Q	
173	*Microtus sp.*	R	Partial dentary with m1-m2	5T	R/P Silt	
174	*Microtus sp.*	R	Partial m1	5T	R/P Silt	
175	*Microtus sp.*	L	m1	5T	R/P Silt	
176	*Microtus sp.*	L	m1	5T	R/P Silt	
177	*Microtus sp.*	R	m1	5T	R/P Silt	
178	*Microtus sp.*	R	m1	5T	R/P Silt	
179	*Microtus sp.*	L	m1	5T	R/P Silt	
180	*Microtus sp.*	R	m1	5T	R/P Silt	
181	*Microtus sp.*	L	Partial dentary with i1, m1	5T	R/P Silt	
182	*Microtus sp.*	L	Partial dentary with m1-m2	5T	R/P Silt	juvenile
183	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
184	*Microtus sp.*	R	m1	5T	R/P Silt	
185	*Microtus sp.*	R	m1	5T	R/P Silt	

Appendix 6 continued.

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
186	*Microtus sp.*	R	m1	5T	R/P Silt	
187	*Microtus sp.*	R	m1	5T, T6/T7 closed	R/P Silt	
188	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
189	*Microtus sp.*	L	m1	5T	R/P Silt	
190	*Microtus sp.*	L	m1	5T	R/P Silt	
191	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
192	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
193	*Arvicolinae*	R	m1	-	R/P Silt	
194	*Microtus sp.*	L	m1	5T	R/P Silt	
195	*Microtus sp.*	R	m1	5T	R/P Silt	
196	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
197	*Microtus sp.*	L	m1	5T	R/P Silt	
198	*Microtus sp.*	R	m1	5T	R/P Silt	
199	*Microtus sp.*	R	Partial dentary with m1-m2	5T	R/P Silt	
200	*Lemmiscus curtatus*	R	Dentary with i1, m1-m2	5T	R/P Silt	
201	*Microtus sp.*	L	m1	5T	R/P Silt	
202	*Microtus sp.*	L	m1	5T	R/P Silt	
203	*Microtus sp.*	R	m1	-	R/P Silt	
204	*Microtus sp.*	L	m1	5T	R/P Silt	
205	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
206	*Microtus sp.*	R	m1	5T	R/P Silt	
207	*Microtus sp.*	R	m1	5T	R/P Silt	
208	*Microtus sp.*	R	m1	5T	R/P Silt	
209	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
210	*Microtus sp.*	R	m1	5T	R/P Silt	
211	*Microtus sp.*	L	Partial dentary with m1 (broken)	6T	U/Q	
212	*Microtus paroperarius*	R	m1	-	R/P Silt	
213	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
214	*Microtus sp.*	R	Partial dentary with m1-m2	6T	R/P Silt	
215	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T, T6 pinched	R/P Silt	
216	*Microtus sp.*	L	Partial dentary with m1-m2	6T	R/P Silt	
217	*Microtus sp.*	L	m1	5T	R/P Silt	
218	*Microtus sp.*	L	m1	5T	R/P Silt	
219	*Microtus sp.*	L	m1	6T	R/P Silt	
220	*Microtus sp.*	R	m1	5T	R/P Silt	
221	*Microtus sp.*	L	m1	5T	R/P Silt	
222	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
223	*Microtus sp.*	R	m1	5T	R/P Silt	
224	*Microtus sp.*	R	m1	5T	R/P Silt	
225	*Microtus sp.*	R	m1	5T	R/P Silt	
226	*Microtus sp.*	R	m1	5T	R/P Silt	
227	*Microtus sp.*	L	m1	5T	R/P Silt	
228	*Arvicolinae*	R	m1?		R/P Silt	
229	*Microtus sp.*	L	Partial dentary with m1	5T	R/P Silt	
230	*Microtus sp.*	L	m1	5T	R/P Silt	
231	*Microtus sp.*	L	m1	5T	R/P Silt	
232	*Microtus sp.*	R	m1	5T	R/P Silt	

Appendix 6 continued.

S.N.	Taxon	Side	Element	Morphotype	Strat. Unit	Misc.
233	*Microtus sp.*	L	m1	5T	R/P Silt	
234	*Microtus sp.*	R	Partial dentary with m1-m2	5T	R/P Silt	
235	*Microtus sp.*	R	Partial dentary with m1	5T	R/P Silt	juvenile
236	*Microtus sp.*	L	m1	5T, T6 w/ incipient closure	R/P Silt	
237	*Microtus sp.*	R	Partial dentary with i1, m1-m2	5T	R/P Silt	
238	*Microtus sp.*	L	m1	5T	R/P Silt	
239	*Microtus sp.*	L	m1	5T	R/P Silt	
240	*Microtus sp.*	R	m1	6T	R/P Silt	
241	*Microtus sp.*	R	m1	5T	R/P Silt	
242	*Microtus sp.*	R	m1	5T	R/P Silt	
243	*Microtus sp.*	R	m1	6T	R/P Silt	
244	*Microtus sp.*	L	m1	5T	R/P Silt	
245	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
246	*Microtus sp.*	L	m1	5T	R/P Silt	
247	*Microtus sp.*	L	m1	5T	R/P Silt	
248	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
249	*Microtus sp.*	L	m1	5T	R/P Silt	
250	*Microtus sp.*	L	m1	7T	R/P Silt	
251	*Microtus sp.*	R	m1	5T	R/P Silt	
252	*Microtus sp.*	L	m1	6T	R/P Silt	
253	*Microtus sp.*	L	m1	5T	R/P Silt	
254	*Microtus sp.*	R	m1	5T, T6/T7 closed from cap	R/P Silt	
255	*Microtus sp.*	R	m1	5T	R/P Silt	
256	*Microtus sp.*	L	m1	6T	R/P Silt	
257	*Microtus sp.*	L	m1	5T	R/P Silt	
258	*Microtus sp.*	R	m1	5T	R/P Silt	
259	*Microtus sp.*	R	m1	5T	R/P Silt	
260	*Microtus sp.*	L	m1	5T	R/P Silt	
261	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
262	*Microtus sp.*	R	Dentary with m1-m2	6T	R/P Silt	
263	*Microtus sp.*	L	Partial dentary with i1, m1	5T	R/P Silt	
264	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	R/P Silt	
265	*Microtus sp.*	L	m1	5T	R/P Silt	digested
266	*Microtus sp.*	L	m1	5T	R/P Silt	
267	*Microtus sp.*	L	m1	5T	R/P Silt	
268	*Microtus sp.*	L	m1	5T, T6 pinched	R/P Silt	
269	*Microtus sp.*	R	m1	5T	R/P Silt	
270	*Microtus sp.*	L	m1	5T	R/P Silt	
271	*Microtus sp.*	L	m1	5T	R/P Silt	
272	*Microtus sp.*	R	m1	5T	R/P Silt	
273	*Microtus sp.*	L	m1	5T	R/P Silt	
274	*Microtus sp.*	L	m1	5T	R/P Silt	
275	*Microtus sp.*	L	m1	5T	R/P Silt	
276	*Microtus sp.*	L	m1	5T	R/P Silt	
277	*Microtus sp.*	L	m1	5T	R/P Silt	
278	*Microtus sp.*	L	m1	5T	R/P Silt	
279	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
280	*Microtus sp.*	L	m1	5T	R/P Silt	
281	*Microtus sp.*	L	Dentary with i1, m1-m2	5T	R/P Silt	
282	*Microtus sp.*	R	m1	5T	R/P Silt	

Appendix 6 continued.

283	*Microtus sp.*	R	m1	5T	R/P Silt	
284	*Microtus sp.*	R	m1	5T	R/P Silt	
285	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
286	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
287	*Lemmiscus curtatus*	L	m1	5T	R/P Silt	
288	*Microtus sp.*	L	m1	5T	R/P Silt	
289	*Microtus sp.*	R	m1	5T	R/P Silt	
290	*Microtus sp.*	L	m1	5T	R/P Silt	
291	*Lemmiscus curtatus*	R	m1	4T, T5 w/ incipient closure	R/P Silt	
292	*Microtus sp.*	R	m1	5T	R/P Silt	
293	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
294	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
295	*Microtus sp.*	R	Dentary with i1, m1-m2	5T	R/P Silt	
296	*Lemmiscus curtatus*	R	m1	5T	R/P Silt	
297	*Microtus sp.*	R	Partial Dentary with i1, m1-m2	5T	R/P Silt	

Appendix 7. Provenience Data Associated with Individual Specimens by Stratigraphic Level for Smith Creek Cave.

Data in brackets represents data listed on bone bags from which individual specimens were separated. <SD> indicates that a single SD (= Surface Depth?) was written on the bag label in such a manner that it appears to apply to all associated numbers (e.g. SW 62-80 SD). Multiple specimens from a given provenience are indicated by a double dash separating the first and last specimens in the sequence (e.g., SCCAR-2--SCCAR-14).

Reddish-Pink Silt--(26WP46, TP #2, 50-60 cm): SCCAR-1; (26WP46, Baulk #1/#2, Stratum 3, 25-40 cm B.S., Red silt and rock frags., July 20/71): SCCAR-2--SCCAR-14; (26WP46, Baulk #1/#2, 70-80 cm B.S., Stratum 5, Red Silt and rock, RM, July 24/71): SCCAR-15--SCCAR-17; (26WP46, TP #2, 60-70 cm, RM, July 18/71): SCCAR-18; (26WP46, Bulk, #1/#2, 0-70 cm, Stratum 5, Red Silt): SCCAR-19--SCCAR-20; (26WP46, TP #2, 90-100 cm): SCCAR-21--SCCAR-25; (26WP46/481, Level Bag TP3, Reddish/Pink Silt, 30-40 cm below surface of silt): SCCAR-31--SCCAR-44; (26WP46, TP #2, 100-110 cm): SCCAR-45--SCCAR-47; (26WP46, Baulk ext., Stratum 5, 50-60 cm): SCCAR-49; (26WP46, TP 3, North 50 cm, Red Layer): SCCAR-50--SCCAR-56; (26WP46, TP 3, "Pink Layer", NW 38-71 <SD>, SW 62-80 <SD>, SE 82-86 <SD>, SJM, 7/12/74): SCCAR-57--SCCAR-90; (26WP46/488, Level Bag TP 3, Depth: 40-50 cm below surface of reddish/pink silt): SCCAR-91--SCCAR-100; (26WP46, Baulk #1/#2, 90-110, Stratum 5): SCCAR-101--SCCAR-106; (26WP46, Baulk #1/#2, 180-190 cm BS, Stratum 5, Red Silt and Rock): SCCAR-107--SCCAR-112; (26WP46, Baulk #1/#2, 140-150, Stratum 5): SCCAR-113--SCCAR-114; (26WP46, Baulk #1/#2, Stratum 5, 50-60): SCCAR-117--SCCAR-123; (26WP46, TP #3 70-80 cm in W half, 60-70 cm in E half, Northernmost 50 cm): SCCAR-124; (26WP46, TP 3, Northernmost 50 cm, 90-100 in W half): SCCAR-125; (26WP46, TP 3, Red Layer, To 40 in E half, 50 in W half, North 50 cm): SCCAR-126; (26WP46, TP 3, Top of Red Layer): SCCAR-127--SCCAR-133; (26WP46/437, TP3, "Bones", "Pink Layer", NW 38-71 <SD>, SW 62-80 <SD>, SE 82-86 <SD>, 7/10/74, 7/11/74, SJM): SCCAR-134--SCCAR-159; (26WP46, Baulk #1/#2, 130-140 cm BS, Stratum 5): SCCAR-160--SCCAR-161;(26WP46, Baulk #1/#2, 150-160 cm B.S., Stratum 5, Red Silt and Rock, RM, July 26/71): SCCAR-162--SCCAR-164; (26WP46, Baulk #1/#2, Stratum 5, 120-130 cm): SCCAR-165--SCCAR-168; (26WP46, Baulk ½, 50-60, Stratum 3): SCCAR-173--SCCAR-180; (26WP46/472, Level Bag TP 3, Reddish/pink silt zone, 20-30 cm below surface of silt): SCCAR-181--SCCAR-198; (26WP46/495, Level Bag TP 3, Reddish Pink Silt, 70-90 cm below surface of silt zone): SCCAR-199--SCCAR-206; (26WP46, Baulk Extension, #1/#2, Stratum 5, Red Silt and Rock, 40-50 cm, RM, July 22, 71): SCCAR-207--SCCAR-210; (26WP46, Baulk ½, 170-180, Stratum 5): SCCAR-212; (26WP46/490, Level Bag – reddish/pink silt zone, Depth 50-60 cm below surface of silt): SCCAR-213--SCCAR-224; (TP 2, RM, 30-50 cm BS, Teeth): SCCAR-225--SCCAR-252; (26WP46/492, Level Bag TP 3, Reddish/Pink Silt, Depth 60-70 cm below surface of reddish pink silt): SCCAR-253—

Appendix 7 continued.

SCCAR-261; (TP 2, RM, 30-50 cm, Teeth): SCCAR-262--SCCAR-266; (26WP46/468, Bone Fragments, From reddish/pink silt, 0-20 cm below surface of silt): SCCAR-267--SCCAR-294, SCCAR-297; (26WP46, TP 3, General Red Layer): SCCAR-295--SCCAR-296.

Rodent Dung and Brown Silt--(26WP 46, Layer #2, TP 2, 20-30 cm): SCCAR-26--SCCAR-30.

Unknown/Questionable Provenience--(26WP46, TP 3, 80-90 W, 70-80 E): SCCAR-48; 26WH?/30, Level Bag, 30-40 cm below surface): SCCAR-115; (26WP46, TP 4, Baulk ¼, SD 10-20, Layer #2): SCCAR-169--SCCAR-172; (26WP46, TP 4, S.D., [SW 70 SE 64 NE 83 NW 77 to 1 m]): SCCAR-211.

APPENDIX 8. IDENTIFIED LAGOMORPHS FROM CATHEDRAL CAVE BY TAXON AND PROVENIENCE.

Measurements of length (*l*) and width (*w*) of the third premolar (p3) are in millimeters. I note specimens that were cleaned using 10% glacial acetic acid in order to distinguish specimens naturally exhibiting acid etching (partial digestion) from specimens where etching may be caused by acid preparation (acid prep.). # = unique specimen number associated with Cathedral Cave locality number TMM 43693 (i.e., TMM 43693-1748 is the full number for the first specimen listed below).

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1748	*Aztlanolagus agilis*	L	p3	2.1	2.1	2N 3E 40-45 cmbd	
1749	*Aztlanolagus agilis*	R	p3	2.4	2.7	2N 3E 40-45 cmbd	
1750	*Aztlanolagus agilis*	R	p3	2.6	2.5	1N 3E Cemented Level	
1751	*Aztlanolagus agilis*	L	p3	2.6	2.3	1N 3E 43.5-55 cmbd; below Cemented Level	acid prep.
1752	*Aztlanolagus agilis*	L	p3	2.6	2.4	1N 3E 43.5-55 cmbd; below Cemented Level	
1753	*Aztlanolagus agilis*	L	p3	2.5	2.1	2N 2-3E 45-60 cmbd	
1754	*Aztlanolagus agilis*	R	p3	-	-	2N 2-3E 45-60 cmbd	juvenile
1755	*Aztlanolagus agilis*	R	p3	2.3	2.3	2N 2-3E 45-60 cmbd	
1756	*Aztlanolagus agilis*	L	p3	2.1	1.2	1N 2E 55-60 cmbd	
1757	*Aztlanolagus agilis*	L	p3	2.6	2.4	1N 2E 60-65 cmbd	
1758	*Aztlanolagus agilis*	L	p3	2.6	2.5	2N 2-3E 60-65 cmbd	
1759	*Aztlanolagus agilis*	R	p3	2.8	2.6	2N 2-3E 60-65 cmbd	
1760	*Aztlanolagus agilis*	L	p3	2.3	2.1	1N 2E 65-70 cmbd	
1761	*Aztlanolagus agilis*	L	p3	2.2	2.1	1N 2E 65-70 cmbd	
1486	*Aztlanolagus agilis*	R	p3	2.5	2.8	1N 3E 65-70 cmbd	
1762	*Aztlanolagus agilis*	R	p3	2.2	2.0	2N 2-3E 65-70 cmbd	
1763	*Aztlanolagus agilis*	L	p3	2.5	2.3	2N 2-3E 65-70 cmbd	
1764	*Aztlanolagus agilis*	L	p3	2.6	2.5	2N 2-3E 70-75 cmbd	
1765	*Aztlanolagus agilis*	L	p3	2.4	2.3	2N 2-3E 70-75 cmbd	
1766	*Aztlanolagus agilis*	R	p3	1.7	1.7	1N 2-3E 75-80 cmbd	digested?
1767	*Aztlanolagus agilis*	R	p3	2.5	2.5	2N 2-3E 75-80 cmbd	
1768	*Aztlanolagus agilis*	L	p3	2.5	2.1	2N 2-3E 80-85 cmbd	
1769	*Aztlanolagus agilis*	L	p3	2.2	2.1	1N 2-3E 85-90 cmbd	
1770	*Aztlanolagus agilis*	R	p3	2.5	2.5	1-2N 2-3E 87-102 cmbd; below pedestaled rocks	
1771	*Aztlanolagus agilis*	R	p3	2.5	2.6	2N 2-3E 90-95 cmbd	
1772	*Aztlanolagus agilis*	R	p3	2.3	2.5	2N 2-3E 90-95 cmbd	
1773	*Brachylagus coloradoensis*	L	dentary with p3-p4	1.6	1.6	1N 2E 65-70 cmbd	
1774	*Brachylagus coloradoensis*	R	p3	1.8	1.8	2N 2-3E 80-85 cmbd	
1775	*Brachylagus idahoensis*	L	p3	1.4	1.2	1N 2E 25-30 cmbd	
1776	*Brachylagus idahoensis*	R	p3	1.8	1.8	2N 2-3E 45-60 cmbd	
1777	*Brachylagus idahoensis*	L	p3	1.8	1.6	2N 2-3E 75-80 cmbd	
1778	Leporidae	R	p3	-	-	1N 3E 30-35 cmbd	digested
1779	Leporidae	R	p3	-	-	2N 2E E Half Cemented Level	

Appendix 8 continued.

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1780	Leporidae	R	p3	2.0	-	1N 2-3E 70-75 cmbd	juvenile?; digested?
1781	*Ochotona* sp.	L	p3	1.2	1.2	1N 3E 45-70 cmbd; Wall Collapse	
1782	*Ochotona* sp.	R	p3	1.2	1.5	1N 3E 45-70 cmbd; Wall Collapse	
1783	*Ochotona* sp.	R	p3	-	-	1N 3E 45-70 cmbd; Wall Collapse	juvenile
1784	*Ochotona* sp.	L	p3	1.1	1.2	1N 3E 45-70 cmbd; Wall Collapse	
1785	*Ochotona* sp.	R	p3	-	-	1N 2E 30-35 cmbd	
1786	*Ochotona* sp.	R	p3	1.2	1.3	1N 3E 35-40 cmbd	
1787	*Ochotona* sp.	L	p3	1.1	1.2	1N 2E 40-45 cmbd	
1788	*Ochotona* sp.	L	p3	1.1	1.0	1N 2E 40-45 cmbd	
1789	*Ochotona* sp.	R	p3	1.3	1.5	1N 3E 40-45 cmbd	
1790	*Ochotona* sp.	L	p3	1.5	1.6	2N 3E 40-45 cmbd	
1791	*Ochotona* sp.	R	p3	-	-	2N 3E 40-45 cmbd	juvenile
1792	*Ochotona* sp.	L	p3	1.4	1.6	1N 3E Cemented Level	
1793	*Ochotona* sp.	R	p3	1.4	1.7	1N 3E Cemented Level	
1794	*Ochotona* sp.	R	p3	1.3	1.4	1N 3E Cemented Level	
1795	*Ochotona* sp.	R	p3	1.3	1.3	1N 3E Cemented Level	
1796	*Ochotona* sp.	L	p3	1.5	-	2N 2E E Half Cemented Level	
1797	*Ochotona* sp.	R	p3	1.2	1.1	1N 3E 43.5-55 cmbd; below Cemented Level	acid prep.
1798	*Ochotona* sp.	R	p3	1.3	1.4	1N 3E 43.5-55 cmbd; below Cemented Level	
1799	*Ochotona* sp.	R	dentary with m1-m3	-	-	1N 3E 43.5-55 cmbd; below Cemented Level	fragment
457	*Ochotona* sp.	L	p3	1.0	1.2	2N 2-3E 45-60 cmbd	digested
470	*Ochotona* sp.	R	p3	1.1	1.3	2N 2-3E 45-60 cmbd	
471	*Ochotona* sp.	L	p3	1.3	1.4	2N 2-3E 45-60 cmbd	
1800	*Ochotona* sp.	R	p3	1.3	1.3	2N 2-3E 45-60 cmbd	
1801	*Ochotona* sp.	R	p3	1.2	1.4	2N 2-3E 45-60 cmbd	
1802	*Ochotona* sp.	R	dentary with p4-m3	-	-	2N 2-3E 45-60 cmbd	
1803	*Ochotona* sp.	L	p3	1.3	1.2	1N 2E 50-55 cmbd	
1804	*Ochotona* sp.	L	p3	1.3	1.3	1N 2E 55-60 cmbd	
1805	*Ochotona* sp.	R	dentary with p4-m1 or m1-m2	-	-	1N 2E 55-60 cmbd	fragment
1806	*Ochotona* sp.	L	p3	1.3	1.6	1N 2E 55-60 cmbd	
1807	*Ochotona* sp.	R	p3	1.3	1.5	1N 2E 55-60 cmbd	
1808	*Ochotona* sp.	R	p3	1.2	1.4	1N 2E 55-60 cmbd	
1809	*Ochotona* sp.	L	p3	1.3	1.4	1N 2E 55-60 cmbd	
1810	*Ochotona* sp.	R	p3	1.3	1.5	1N 3E 55-60 cmbd	
1811	*Ochotona* sp.	R	dentary	-	-	1N 3E 55-60 cmbd	edentulous
1812	*Ochotona* sp.	R	dentary with m1-m2	-	-	1N 2E 60-65 cmbd	
1813	*Ochotona* sp.	L	p3	1.3	1.6	1N 2E 60-65 cmbd	
1814	*Ochotona* sp.	L	p3	1.2	1.2	1N 3E 60-65 cmbd	
1815	*Ochotona* sp.	L	p3	1.2	1.2	1N 3E 60-65 cmbd	juvenile?
1816	*Ochotona* sp.	L	p3	1.2	1.1	2N 2-3E 60-65 cmbd	
1817	*Ochotona* sp.	R	p3	1.3	1.5	2N 2-3E 60-65 cmbd	

Appendix 8 continued.

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1818	*Ochotona* sp.	R	p3	1.0	1.1	2N 2-3E 60-65 cmbd	juvenile?
1819	*Ochotona* sp.	R	p3	1.3	1.4	2N 2-3E 60-65 cmbd	
1820	*Ochotona* sp.	R	p3	1.3	1.2	1N 2E 65-70 cmbd	
1821	*Ochotona* sp.	L	p3	1.3	1.5	1N 2E 65-70 cmbd	
1310	*Ochotona* sp.	R	p3	1.2	1.2	1N 3E 65-70 cmbd	digested
1311	*Ochotona* sp.	R	p3	1.3	1.4	1N 3E 65-70 cmbd	
1822	*Ochotona* sp.	L	p3	1.3	1.3	2N 2-3E 65-70 cmbd	
1823	*Ochotona* sp.	R	p3	1.1	1.1	2N 2-3E 65-70 cmbd	
1824	*Ochotona* sp.	R	p3	1.4	1.4	2N 2-3E 65-70 cmbd	
1825	*Ochotona* sp.	L	p3	1.5	1.3	2N 2-3E 65-70 cmbd	
884	*Ochotona* sp.	L	p3	1.1	-	1N 2-3E 70-75 cmbd	
1826	*Ochotona* sp.	R	p3	1.3	1.5	1N 2-3E 70-75 cmbd	
1827	*Ochotona* sp.	R	p3	1.1	1.3	2N 2-3E 70-75 cmbd	
1828	*Ochotona* sp.	R	dentary with p3-p4	1.1	1.3	1N 2-3E 75-80 cmbd	fragment
1829	*Ochotona* sp.	R	p3	1.3	1.3	1N 2-3E 75-80 cmbd	
1830	*Ochotona* sp.	L	p3	1.2	1.3	1N 2-3E 75-80 cmbd	
1831	*Ochotona* sp.	L	p3	1.2	1.2	2N 2-3E 75-80 cmbd	
1832	*Ochotona* sp.	L	p3	1.2	1.2	2N 2-3E 75-80 cmbd	
1833	*Ochotona* sp.	L	p3	1.2	1.1	2N 2-3E 75-80 cmbd	
1834	*Ochotona* sp.	L	p3	1.0	1.1	2N 2-3E 75-80 cmbd	
1835	*Ochotona* sp.	L	p3	1.1	1.0	2N 2-3E 75-80 cmbd	
1836	*Ochotona* sp.	L	p3	1.1	1.2	2N 2-3E 75-80 cmbd	
1837	*Ochotona* sp.	R	p3	-	-	1N 2-3E 80-85 cmbd	juvenile
1839	*Ochotona* sp.	R	p3	1.3	1.3	2N 2-3E 80-85 cmbd	
1840	*Ochotona* sp.	R	p3	1.3	1.3	2N 2-3E 80-85 cmbd	
1841	*Ochotona* sp.	R	p3	-	-	2N 2-3E 80-85 cmbd	juvenile
1842	*Ochotona* sp.	L	p3	1.3	1.6	1N 2-3E 85-90 cmbd	
1843	*Ochotona* sp.	L	p3	1.3	1.3	1N 2-3E 85-90 cmbd	
1844	*Ochotona* sp.	L	p3	1.2	1.2	1N 2-3E 85-90 cmbd	
1845	*Ochotona* sp.	R	p3	1.1	1.2	2N 2-3E 85-90 cmbd	
1846	*Ochotona* sp.	L	p3	1.3	1.3	2N 2-3E 85-90 cmbd	
1847	*Ochotona* sp.	R	p3	1.1	1.2	2N 2-3E 85-90 cmbd	
1848	*Ochotona* sp.	R	p3	-	-	2N 2-3E 85-90 cmbd	juvenile
1849	*Ochotona* sp.	R	p3	1.2	1.3	2N 2-3E 85-90 cmbd and below	fragment
1850	*Ochotona* sp.	L	p3	1.0	1.0	2N 3E 85-110 cmbd; below flowstone	
1851	*Ochotona* sp.	L	p3	1.2	1.3	2N 3E 85-110 cmbd; below flowstone	
1852	*Ochotona* sp.	L	p3	1.3	1.4	2N 3E 85-110 cmbd; below flowstone	
1853	*Ochotona* sp.	R	p3	1.2	1.3	2N 3E 85-110 cmbd; below flowstone	
1854	*Ochotona* sp.	L	p3	1.2	1.3	1-2N 2-3E 87-102 cmbd; below pedestaled rocks	
1855	*Ochotona* sp.	R	dentary with p3-p4	1.1	1.1	1-2N 2-3E 87-102 cmbd; below pedestaled rocks	partial
1856	*Ochotona* sp.	R	p3	1.2	1.5	2N 2-3E 90-95 cmbd	
1857	*Ochotona* sp.	L	p3	1.3	1.4	2N 2-3E 90-95 cmbd	
1858	*Ochotona* sp.	L	p3	1.3	1.4	2N 2-3E 90-95 cmbd	

Appendix 8 continued.

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1859	*Ochotona* sp.	L	p3	-	-	1N 2-3E 90 cmbd and below	juvenile
1860	*Ochotona* sp.	R	p3	-	-	2N 2-3E 95-102 cmbd	digested
1861	*Ochotona* sp.	R	p3	1.4	1.5	2N 3E 100-105 cmbd	
1862	*Ochotona* sp.	L	p3	1.4	1.4	2N 3E 100-105 cmbd	
1863	*Ochotona* sp.	R	p3	1.3	1.4	2N 3E 100-105 cmbd	
1864	*Ochotona* sp.	R	p3	1.3	1.6	2N 3E 100-105 cmbd	
1865	Ochotonidae	R	p3	-	-	1N 2E 65-70 cmbd	fragment
1866	*Sylvilagus* or *Lepus* sp.	R	p3	2.9	3.1	1N 3E 25-60 cmbd; Wall Scrapings	
1867	*Sylvilagus* or *Lepus* sp.	R	p3	3.4	3.2	1N 3E 45-70 cmbd; Wall Collapse	
1868	*Sylvilagus* or *Lepus* sp.	R	p3	3.3	3.2	2N 3E 30-35 cmbd	
1869	*Sylvilagus* or *Lepus* sp.	L	p3	1.7	1.5	2N 3E 40-45 cmbd	
1870	*Sylvilagus* or *Lepus* sp.	R	p3	2.4	2.4	2N 3E 40-45 cmbd	
1871	*Sylvilagus* or *Lepus* sp.	L	p3	2.7	2.6	2N 3E 40-45 cmbd	
1872	*Sylvilagus* or *Lepus* sp.	L	p3	2.5	1.8	1N 3E Cemented Level	
1873	*Sylvilagus* or *Lepus* sp.	R	p3	3.2	3.2	2N 2E E Half Cemented Level	
1874	*Sylvilagus* or *Lepus* sp.	R	dentary with p3-p4	2.4	2.2	1N 3E 43.5-55 cmbd; below Cemented Level	partial
1875	*Sylvilagus* or *Lepus* sp.	L	p3	3.1	3.0	1N 3E 43.5-55 cmbd; below Cemented Level	
1876	*Sylvilagus* or *Lepus* sp.	R	p3	3.1	2.9	1N 3E 43.5-55 cmbd; below Cemented Level	
1877	*Sylvilagus* or *Lepus* sp.	R	p3	2.1	2.0	1N 3E 43.5-55 cmbd; below Cemented Level	
1878	*Sylvilagus* or *Lepus* sp.	R	p3	2.3	2.2	1N 3E 43.5-55 cmbd; below Cemented Level	
1879	*Sylvilagus* or *Lepus* sp.	R	p3	3.2	3.0	2N 2-3E 45-60 cmbd	
1880	*Sylvilagus* or *Lepus* sp.	L	p3	2.5	2.2	2N 2-3E 45-60 cmbd	
1881	*Sylvilagus* or *Lepus* sp.	L	p3	3.4	2.6	2N 2-3E 45-60 cmbd	
1882	*Sylvilagus* or *Lepus* sp.	L	p3	3.9	3.5	2N 2-3E 45-60 cmbd	
1883	*Sylvilagus* or *Lepus* sp.	R	p3	2.4	2.4	2N 2-3E 45-60 cmbd	
463	*Sylvilagus* or *Lepus* sp.	L	p3	2.0	1.7	2N 2-3E 45-60 cmbd	juvenile
452	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	2N 2-3E 45-60 cmbd	fragment
480	*Sylvilagus* or *Lepus* sp.	L	p3	2.2	1.2	2N 2-3E 45-60 cmbd	juvenile; acid prep.
1884	*Sylvilagus* or *Lepus* sp.	L	p3	2.7	2.5	2N 2-3E 45-60 cmbd	
1885	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	2N 2-3E 45-60 cmbd	juvenile; acid prep.

Appendix 8 continued.

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1886	*Sylvilagus* or *Lepus* sp.	R	p3	3.3	3.0	2N 2-3E 45-60 cmbd	
1887	*Sylvilagus* or *Lepus* sp.	L	p3	3.3	2.8	1N 2E 50-55 cmbd	
1888	*Sylvilagus* or *Lepus* sp.	R	p3	3.2	3.0	1N 2E 55-60 cmbd	
1889	*Sylvilagus* or *Lepus* sp.	R	p3	3.5	3.6	1N 3E 55-60 cmbd	
1890	*Sylvilagus* or *Lepus* sp.	L	p3	2.1	2.0	1N 2E 60-65 cmbd	juvenile?
1891	*Sylvilagus* or *Lepus* sp.	L	p3	-	-	1N 3E 60-65 cmbd	digested
1892	*Sylvilagus* or *Lepus* sp.	R	dentary with p3-m2	2.5	2.5	1N 3E 60-65 cmbd	partial
1893	*Sylvilagus* or *Lepus* sp.	R	p3	3.0	2.7	2N 2-3E 60-65 cmbd	
1894	*Sylvilagus* or *Lepus* sp.	L	p3	-	-	1N 2E 65-70 cmbd	juvenile
1895	*Sylvilagus* or *Lepus* sp.	R	p3	3.6	3.4	1N 2E 65-70 cmbd	
1896	*Sylvilagus* or *Lepus* sp.	R	p3	2.5	2.2	1N 3E 65-70 cmbd	digested?
1897	*Sylvilagus* or *Lepus* sp.	R	p3	2.8	2.4	1N 3E 65-70 cmbd	
1898	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	1N 2-3E 70-75 cmbd	juvenile
1899	*Sylvilagus* or *Lepus* sp.	L	p3	3.3	2.8	1N 2-3E 70-75 cmbd	
1900	*Sylvilagus* or *Lepus* sp.	R	p3	3.3	2.9	2N 2-3E 70-75 cmbd	
1901	*Sylvilagus* or *Lepus* sp.	R	p3	2.9	2.5	2N 2-3E 70-75 cmbd	
1902	*Sylvilagus* or *Lepus* sp.	R	p3	2.9	2.8	2N 2-3E 70-75 cmbd	
1903	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	2N 2-3E 70-75 cmbd	juvenile?
1904	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	2N 2-3E 70-75 cmbd	juvenile
1905	*Sylvilagus* or *Lepus* sp.	R	p3	-	3.5	2N 2-3E 70-75 cmbd	fragment
1906	*Sylvilagus* or *Lepus* sp.	L	p3	2.3	2.0	2N 2-3E 70-75 cmbd	digested
1907	*Sylvilagus* or *Lepus* sp.	L	p3	3.0	2.6	2N 2-3E 75-80 cmbd	acid prep.
1908	*Sylvilagus* or *Lepus* sp.	L	p3	3.0	2.8	2N 2-3E 75-80 cmbd	
1909	*Sylvilagus* or *Lepus* sp.	R	p3	2.9	2.9	2N 2-3E 75-80 cmbd	
1910	*Sylvilagus* or *Lepus* sp.	R	dentary with p3-m2	3.6	3.4	2N 2-3E 75-80 cmbd	digested?
1911	*Sylvilagus* or *Lepus* sp.	L	p3	3.7	-	1N 2-3E 80-85 cmbd	
1912	*Sylvilagus* or *Lepus* sp.	R	p3	2.7	2.6	2N 2-3E 80-85 cmbd	

Appendix 8 continued.

#	Taxon	Side	Element	*l*	*w*	Provenience	Comments
1913	*Sylvilagus* or *Lepus* sp.	L	p3	-	-	2N 2-3E 80-85 cmbd	fragment
1914	*Sylvilagus* or *Lepus* sp.	L	p3	-	-	2N 2-3E 80-85 cmbd	fragment
1915	*Sylvilagus* or *Lepus* sp.	L	p3	3.0	2.5	2N 2-3E 80-85 cmbd	
1916	*Sylvilagus* or *Lepus* sp.	R	p3	3.4	3.7	2N 2-3E 80-85 cmbd	
1917	*Sylvilagus* or *Lepus* sp.	R	p3	-	-	2N 2-3E 80-85 cmbd	fragment
1918	*Sylvilagus* or *Lepus* sp.	L	P3	-	-	2N 2-3E 90-95 cmbd	juvenile
1919	*Sylvilagus* or *Lepus* sp.	L	dentary with p3-m2	-	-	2N 2-3E 90-95 cmbd	partial; juvenile
1119	*Sylvilagus* or *Lepus* sp.	L	p3	2.9	2.7	2N 3E 85-110 cmbd; below flowstone	
1920	*Sylvilagus* or *Lepus* sp.	L	p3	-	-	2N 3E 100-105 cmbd	fragment

Appendix 9. List of Specimens of *Neotoma* from Cathedral Cave evaluated for this study.

Measurements of occlusal length (*l*), occlusal width of the second loph of the m1 (*w*), and height of the dentine tract (*h*-dt) are in mm.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2732	R	m1	3.9	2.0	1.6	2N 3E 40-56 cmbd; NE Corner Suspect	
2733	L	m1	-	-	-	2N 3E 40-56 cmbd; NE Corner Suspect	fragment
2734	R	m1	3.1	1.5	0.7	2N 3E 40-56 cmbd; NE Corner Suspect	
2735	L	m1	3.3	1.7	2.3	2N 3E 40-56 cmbd; NE Corner Suspect	
2736	R	m1	3.7	1.9	-	2N 3E 40-56 cmbd; NE Corner Suspect	worn
2737	R	m1	2.7	-	-	2N 3E 40-56 cmbd; NE Corner Suspect	digested
2738	R	m1	3.4	1.7	1.1+	2N 3E 40-56 cmbd; NE Corner Suspect	
2739	L	dentary w/ i1, m1-m2	3.3	1.6	-	2N 3E 40-56 cmbd; NE Corner Suspect	juvenile?
2740	L	m1	3.2	1.6	2.0	1N 3E 25-60 cmbd; E Wall scrapings	
2741	R	m1	3.0	1.4	0.3	1N 3E 25-60 cmbd; E Wall scrapings	
2742	L	m1	3.5	1.6	0.5	1N 3E 25-60 cmbd; E Wall scrapings	
2743	R	m1	2.9	1.5	0.3	1N 3E 25-60 cmbd; E Wall scrapings	
2744	R	m1	3.3	1.55	1.0	1N 3E 25-60 cmbd; E Wall scrapings	
2745	L	m1	3.2	1.6	1.1	1N 3E 25-60 cmbd; E Wall scrapings	
2746	R	m1	2.95	1.4	0.8	1N 3E 25-60 cmbd; E Wall scrapings	
2747	L	dentary w/ i1, m1	-	-	-	1N 2E No Provenience; under big rock	worn
2748	L	m1	3.2	1.6	0.6	1N 2E No Provenience; under big rock	
2749	L	m1	-	-	-	1N 2E No Provenience; under big rock	digested
2750	L	m1	-	-	-	1N 2E No Provenience; under big rock	fragment
2751	L	m1	3.1	1.4	1.1	1N 2E No Provenience; under big rock	
2752	L	m1	3.6	1.8	0.9+	1N 2E No Provenience; under big rock	
2753	R	m1	3.15	1.6	1.0+	1N 2E No Provenience; under big rock	
2754	L	m1	3.1	1.7	1.1	1N 2E No Provenience; under big rock	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2755	L	m1	3.5	1.8	1.7	1N 3E Wall Collapse; 45-70 cmbd	
2756	L	m1	3.8	1.85	1.2	1N 3E Wall Collapse; 45-70 cmbd	
2757	R	dentary with m1	-	-	-	1N 3E Wall Collapse; 45-70 cmbd	worn
2758	R	m1	2.9	1.35	1.8	1N 3E Wall Collapse; 45-70 cmbd	juvenile?
2759	L	m1	-	-	-	1N 3E Wall Collapse; 45-70 cmbd	juvenile
2760	R	m1	2.8	1.4	0.6	1N 3E Wall Collapse; 45-70 cmbd	
2761	R	m1	3.0	1.5	1.1	1N 3E Wall Collapse; 45-70 cmbd1N 3E Wall Collapse; 45-70 cmbd	
2762	R	m1	3.4	1.7	1.3	1N 3E Wall Collapse; 45-70 cmbd	
2763	L	m1	2.5	1.2	0	1N 3E Wall Collapse; 45-70 cmbd	juvenile
2764	R	m1	3.15	1.5	1.0	2N 2E East Half; Upper 50 cm	
2765	L	m1	3.7	2.0	1.1+	2N 2E East Half; Upper 50 cm	
2766	R	m1	3.15	1.65	0.7	2N 2E East Half; Upper 50 cm	
2767	L	m1	-	-	-	2N 2E East Half; Upper 50 cm	fragment
2768	L	m1	2.85	1.5	0.5	2N 2E East Half; Upper 50 cm	
2769	L	m1	3.45	-	1.5	2N 2E East Half; Upper 50 cm	digested
2770	R	m1	3.7	1.7	1.0	2N 2E East Half; Upper 50 cm	
2771	R	m1	3.75	-	1.0	2N 2E East Half; Upper 50 cm	digested
2772	L	m1	3.3	1.7	0.4	2N 2E East Half; Upper 50 cm	
2773	R	m1	2.7	1.35	0.4	2N 2E East Half; Upper 50 cm	
2774	R	m1	3.35	1.8	0.6	2N 2E East Half; Upper 50 cm	
2775	R	m1	3.75	1.9	1.6	2N 2E East Half; Upper 50 cm	
2776	R	m1	-	-	-	2N 2E East Half; Upper 50 cm	fragment
2777	R	m1	3.5	1.6	0.6	2N 2E East Half; Upper 50 cm	
2778	L	m1	3.45	1.8	1.8	2N 2E East Half; Upper 50 cm	
2779	R	m1	-	-	-	2N 2E East Half; Upper 50 cm	worn
2780	L	m1	2.8	1.1	0.8	2N 2-3E 45-75 cmbd; South Wall Scrapings	juvenile?

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2781	R	m1	-	-	-	2N 2-3E 45-75 cmbd; South Wall Scrapings	fragment
2782	R	m1	3.6	1.85	1.2+	2N 2-3E 45-75 cmbd; South Wall Scrapings	
2783	L	m1	3.4	1.75	2.1+	2N 2-3E 45-75 cmbd; South Wall Scrapings	digested?
2784	R	m1	-	-	-	1N 3E wall collapse; less than 70 cmbd	fragment
2785	L	m1	3.0	1.5	0.4	1N 3E wall collapse; less than 70 cmbd	
2786	L	m1	3.6	-	0.6	1N 3E wall collapse; less than 70 cmbd	
2787	L	m1	2.85	1.6	0.75	1N 3E wall collapse; less than 70 cmbd	
2788	L	m1	3.6	1.9	1.3	1N 3E wall collapse; less than 70 cmbd	digested
2789	R	m1	3.15	1.6	1.2	1N 3E wall collapse; less than 70 cmbd	juvenile
2790	L	m1	-	-	-	1N 2E 25-65 cmbd; wall scrapings	digested
2791	L	m1	-	1.5	1.7	1N 2E 25-65 cmbd; wall scrapings	
2792	L	m1	3.1	1.65	0.4	1N 2E 25-65 cmbd; wall scrapings	worn
2793	L	m1	2.7	1.3	1.0	1N 2E 25-65 cmbd; wall scrapings	
2794	R	m1	3.6	1.7	0.4	1N 2E 25-65 cmbd; wall scrapings	
2795	L	m1	3.0	1.6	0.3	1N 2E 25-65 cmbd; wall scrapings	
2796	R	m1	3.25	1.7	0.6	1N 3E 32-70 cmbd; North wall scrap	
2797	R	dentary with i1, m1	3.4	1.7	-	1N 3E 25-30 cmbd	partial
2798	L	m1	2.9	1.4	1.55	1N 3E 25-30 cmbd	
2799	L	dentary with m1-m2	3.3	1.6	0.9	1N 3E 25-30 cmbd	partial
2800	L	m1	3.3	1.5	0.6	1N 3E 25-30 cmbd	
2801	L	m1	3.3	1.8	0.3	1N 3E 30-35 cmbd	
2802	R	m1	3.3	1.3	0.45	1N 3E 30-35 cmbd	juvenile?
2803	L	m1	3.8	1.8	0.8	1N 3E 30-35 cmbd	
2804	R	m1	-	-	-	1N 3E 30-35 cmbd	worn
2805	L	m1	3.1	1.5	0.4	1N 3E 30-35 cmbd	
2806	R	m1	2.95	1.7	0.35	1N 3E 30-35 cmbd	
2807	R	m1	3.1	1.5	0.7	2N 3E 30-35 cmbd	
2808	R	m1	3.05	1.45	1.3	2N 3E 30-35 cmbd	
2809	L	m1	-	1.6	2.0	2N 3E 30-35 cmbd	
2810	R	m1	3.2	1.35	1.2	2N 3E 30-35 cmbd	digested
2811	R	m1	3.4	1.6	1.5	2N 3E 30-35 cmbd	
2812	R	m1	3.3	1.6	1.5	1N 2E 35-40 cmbd	
2813	R	m1	-	-	-	1N 2E 35-40 cmbd	worn
2814	L	m1	3.0	1.3	0.9	1N 2E 35-40 cmbd	digested?
2815	R	m1	-	-	-	1N 3E 35-40 cmbd	digested

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2816	R	m1	3.5	1.9	-	1N 3E 35-40 cmbd	
2817	R	m1	3.3	1.65	1.4	1N 3E 35-40 cmbd	
2818	R	m1	3.1	1.55	0.5	1N 3E 35-40 cmbd	
2819	L	m1	-	-	-	1N 3E 35-40 cmbd	fragment
2820	L	m1	3.05	1.5	1.45	1N 3E 35-40 cmbd	
2821	L	m1	-	-	-	1N 3E 35-40 cmbd	juvenile
2822	R	m1	3.75	2.0	1.2+	1N 3E 35-40 cmbd	
2823	L	m1	-	-	-	1N 3E 35-40 cmbd	fragment
2824	L	m1	3.15	1.6	1.8	1N 3E 35-40 cmbd	
2825	L	m1	3.4	1.75	0.9	1N 3E 35-40 cmbd	
2826	R	m1	-	-	-	1N 3E 35-40 cmbd	worn
2827	L	m1	-	-	-	1N 3E 35-40 cmbd	juvenile
2828	R	m1	-	-	-	1N 3E 35-40 cmbd	
2829	R	m1	3.2	1.55	0.45	1N 3E 35-40 cmbd	
2830	L	m1	2.9	1.35	0.7	2N 3E 35-40 cmbd	
2831	R	m1	-	-	-	2N 3E 35-40 cmbd	
2832	R	m1	3.15	1.5	0.9	2N 3E 35-40 cmbd	
2833	L	m1	-	-	-	2N 3E 35-40 cmbd	fragment
2834	R	m1	3.4	1.6	1.2	2N 3E 35-40 cmbd	
2835	L	m1	3.35	1.7	2.0	2N 3E 35-40 cmbd	
2836	R	m1	3.7	1.8	1.2	2N 3E 35-40 cmbd	
2837	R	m1	-	-	-	1N 2E 40-45 cmbd	juvenile
2838	R	m1	3.7	1.8	2.0	1N 2E 40-45 cmbd	
2839	R	m1	-	-	-	1N 2E 40-45 cmbd	worn
2840	R	m1	3.7	1.8	1.5+	1N 2E 40-45 cmbd	
2841	L	m1	-	-	-	1N 3E 40-45 cmbd	fragment; digested
2842	R	m1	-	-	-	1N 3E 40-45 cmbd	fragment
2843	R	m1	-	1.8	1.1	1N 3E 40-45 cmbd	digested
2844	R	m1	3.0	-	0.8	1N 3E 40-45 cmbd	
2845	R	dentary w/ m1	3.15	1.6	-	1N 3E 40-45 cmbd	partial
2846	L	m1	2.9	1.55	0.5	1N 3E 40-45 cmbd	
2847	R	m1	2.6	1.3	0.6	1N 3E 40-45 cmbd	
2848	R	m1	2.85	1.5	0.45	1N 3E 40-45 cmbd	digested
2849	R	m1	3.1	1.5	1.5	2N 3E 40-45 cmbd	
2850	L	m1	3.5	1.75	1.2	2N 3E 40-45 cmbd	
2851	L	m1	2.85	1.35	0.3	2N 3E 40-45 cmbd	
2852	L	m1	3.1	1.5	0.8	2N 3E 40-45 cmbd	
2853	L	m1	3.2	1.5	0.45	2N 3E 40-45 cmbd	
2854	R	m1	3.55	1.7	2.0	2N 3E 40-45 cmbd	
2855	L	m1	2.8	1.5	0.55	2N 3E 40-45 cmbd	
2856	R	m1	-	-	-	2N 3E 40-45 cmbd	digested
2857	R	m1	3.7	1.9	1.2	2N 3E 40-45 cmbd	
2858	L	m1	-	-	-	2N 3E 40-45 cmbd	
2859	R	m1	3.6	1.9	1.3	2N 3E 40-45 cmbd	
2860	L	m1	3.1	1.55	0.3	2N 3E 40-45 cmbd	
2861	L	m1	3.45	-	1.95	2N 3E 40-45 cmbd	digested
2862	R	m1	3.5	1.55	1.35	2N 3E 40-45 cmbd	
2863	R	m1	-	-	-	2N 3E 40-45 cmbd	worn
2864	R	m1	3.45	1.7	1.25	2N 3E 40-45 cmbd	
2865	R	m1	3.2	1.6	0.3	2N 3E 40-45 cmbd	
2866	R	m1	3.75	1.8	1.7	2N 3E 40-45 cmbd	
2867	L	m1	3.35	1.65	1.6	2N 3E 40-45 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2868	L	m1	-	-	-	2N 3E 40-45 cmbd	damaged
2869	L	m1	-	-	-	2N 3E 40-45 cmbd	juvenile; damaged
2870	L	m1	3.05	1.65	0.95	2N 3E 40-45 cmbd	
2871	L	m1	3.25	1.55	1.35	2N 3E 40-45 cmbd	
2872	R	m1	2.9	1.35	1.4	2N 3E 40-45 cmbd	
2873	R	m1	-	-	-	2N 3E 40-45 cmbd	digested
2874	L	m1	3.1	1.6	0.75	2N 3E 40-45 cmbd	
2875	R	m1	-	-	-	2N 3E 40-45 cmbd	juvenile
2876	R	m1	2.9	1.45	-	2N 3E 40-45 cmbd	
2877	L	m1	2.95	1.45	0.6	2N 3E 40-45 cmbd	
2878	L	m1	3.2	1.65	1.1	2N 3E 40-45 cmbd	
2879	L	m1	3.5	1.75	1.15	2N 3E 40-45 cmbd	
2880	L	m1	-	-	-	2N 3E 40-45 cmbd	juvenile
2881	R	m1	2.85	1.55	0.4	2N 3E 40-45 cmbd	
2882	R	m1	3.2	1.6	1.0	2N 3E 40-45 cmbd	
2883	R	m1	3.15	1.55	1.8	2N 3E 40-45 cmbd	
2884	R	m1	3.4	1.6	1.45	2N 3E 40-45 cmbd	
2885	R	m1	-	-	-	2N 3E 40-45 cmbd	worn
2886	R	m1	-	-	-	2N 3E 40-45 cmbd	worn
2887	R	m1	-	-	-	2N 3E 40-45 cmbd	damaged
2888	R	m1	3.25	1.55	1.0	2N 3E 40-45 cmbd	
2889	R	m1	3.35	1.6	0.35	2N 3E 40-45 cmbd	
2890	R	m1	2.85	1.4	0.55	2N 3E 40-45 cmbd	
2891	L	m1	-	-	-	2N 3E 40-45 cmbd	juvenile
2892	L	m1	3.4	1.55	1.1	2N 3E 40-45 cmbd	
2893	L	m1	2.7	1.35	0.4	2N 3E 40-45 cmbd	
2894	L	m1	-	-	-	2N 3E 40-45 cmbd	juvenile
2895	L	m1	2.85	1.55	0.6	2N 3E 40-45 cmbd	
2896	L	m1	3.25	1.65	1.0	2N 3E 40-45 cmbd	
2897	L	m1	-	-	-	2N 3E 40-45 cmbd	fragment
2898	L	m1	3.3	1.65	1.25	2N 3E 40-45 cmbd	
2899	L	m1	2.9	1.5	0.45	2N 3E 40-45 cmbd	
2900	L	m1	3.6	1.85	1.0	2N 3E 40-45 cmbd	
2901	R	m1	-	-	-	1N 2E 45-50 cmbd	fragment
2902	R	m1	3.3	1.65	1.65	1N 3E Cemented Level	
2903	R	m1	3.65	1.7	1.35	1N 3E Cemented Level	
2904	R	m1	3.3	1.7	1.8	1N 3E Cemented Level	
2905	L	m1	3.4	1.6	2.1	1N 3E Cemented Level	
2906	R	m1	3.55	1.4	1.5	1N 3E Cemented Level	
2907	R	m1	3.3	1.65	0.65	1N 3E Cemented Level	
2908	R	m1	-	-	-	1N 3E Cemented Level	worn
2909	R	m1	3.0	1.35	1.0	1N 3E Cemented Level	
2910	R	m1	3.35	1.65	0.85	1N 3E Cemented Level	
2911	L	m1	3.45	1.7	1.15	1N 3E Cemented Level	
2912	R	m1	3.35	1.7	0.3	1N 3E Cemented Level	
2913	R	m1	3.65	1.8	1.5	1N 3E Cemented Level	
2914	R	m1	3.35	1.7	1.65	1N 3E Cemented Level	
2915	R	m1	2.8	1.55	0.35	1N 3E Cemented Level	
2916	R	m1	3.0	1.5	0.95	1N 3E Cemented Level	
2917	L	m1	3.2	1.55	0.95	1N 3E Cemented Level	
2918	L	m1	3.45	1.9	1.55	1N 3E Cemented Level	
2919	L	m1	-	-	-	1N 3E Cemented Level	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2920	L	m1	-	-	-	1N 3E Cemented Level	digested
2921	R	m1	-	-	-	1N 3E Cemented Level	worn
2922	L	m1	-	-	-	1N 3E Cemented Level	digested
2923	L	m1	2.85	1.3	0.6	1N 3E Cemented Level	
2924	L	m1	-	-	-	1N 3E Cemented Level	fragment
2925	L	m1	2.95	1.65	1.0	1N 3E Cemented Level	
2926	L	m1	3.55	1.9	1.0	1N 3E Cemented Level	
2927	L	m1	-	-	-	1N 3E Cemented Level	digested
2928	L	m1	3.85	2.0	0	1N 3E Cemented Level	
2929	R	m1	3.75	1.75	0.85	1N 3E Cemented Level	
2930	L	m1	3.7	1.9	-	1N 3E Cemented Level	worn
2931	L	m1	-	-	-	1N 3E Cemented Level	fragment
2932	R	m1	3.65	1.9	1.5	1N 3E Cemented Level	
2933	L	m1	3.3	1.6	1.2	1N 3E Cemented Level	
2934	L	m1	3.85	1.85	1.15	1N 3E Cemented Level	
2935	L	m1	3.3	1.65	-	1N 3E Cemented Level	damaged
2936	R	m1	3.3	1.8	0.8	1N 3E Cemented Level	
2937	R	m1	3.0	1.4	0.25	1N 3E Cemented Level	
2938	R	m1	2.9	1.35	0.7	1N 3E Cemented Level	
2939	L	m1	-	-	-	1N 3E Cemented Level	digested
2940	R	m1	2.85	1.4	0.85	1N 3E Cemented Level	
2941	L	m1	3.1	1.5	0.25	1N 3E Cemented Level	
2942	L	m1	2.9	1.4	0.1	2N 3E Cemented Level	
2943	R	m1	-	-	-	2N 3E Cemented Level	damaged
2944	L	m1	3.5	1.8	0.8	2N 3E Cemented Level	
2945	R	m1	-	-	-	2N 3E Cemented Level	worn
2946	L	m1	3.55	1.6	1.4	2N 3E Cemented Level	
2947	R	m1	-	-	-	2N 3E Cemented Level	digested
2948	R	m1	3.5	1.75	-	2N 3E Cemented Level	worn
2949	R	m1	3.55	1.8	1.55	2N 3E Cemented Level	
2950	R	m1	3.45	1.75	-	2N 3E Cemented Level	worn
2951	L	m1	-	-	-	2N 3E Cemented Level	worn
2952	R	m1	-	-	-	2N 3E Cemented Level	fragment
2953	L	m1	-	-	-	2N 3E Cemented Level	juvenile
2954	R	m1	-	-	-	2N 3E Cemented Level	digested
2955	R	m1	-	-	-	2N 3E Cemented Level	worn
2956	L	m1	3.4	1.7	1.5	2N 3E Cemented Level	
2957	R	dentary w/ m1	3.6	1.8	1.2	2N 3E Cemented Level	fragment
2958	L	m1	3.15	1.6	1.45	2N 3E Cemented Level	
2959	L	m1	2.45	1.2	-	2N 3E Cemented Level	damaged
2960	L	m1	-	-	-	2N 3E Cemented Level	fragment
2961	L	m1	-	-	-	2N 3E Cemented Level	digested
2962	L	m1	-	-	-	2N 3E Cemented Level	digested
2963	R	m1	3.5	1.7	1.2	2N 3E Cemented Level	
2964	R	m1	3.65	1.8	-	2N 3E Cemented Level	worn
2965	R	m1	-	-	-	2N 3E Cemented Level	fragment
2966	L	m1	2.5	1.55	0.2	2N 3E Cemented Level	
2967	R	m1	-	-	-	2N 3E Cemented Level	worn
2968	L	m1	2.7	1.2	-	2N 3E Cemented Level	damaged
2969	L	m1	-	-	-	2N 3E Cemented Level	fragment
2970	R	m1	-	-	-	2N 3E Cemented Level	juvenile
2971	R	m1	2.95	1.5	0.6	2N 3E Cemented Level	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2972	R	m1	-	-	-	2N 2E East Half; Cemented Level	damaged
2973	R	m1	3.25	1.6	1.5	2N 2E East Half; Cemented Level	
2974	R	m1	3.5	1.6	1.45	2N 2E East Half; Cemented Level	
2975	R	m1	-	-	-	2N 2E East Half; Cemented Level	worn
2976	L	m1	-	-	-	2N 2E East Half; Cemented Level	digested
2977	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2978	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	fragment
2979	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2980	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2981	L	m1	3.1	1.4	0.6	1N 3E 43.5-55 cmbd; below cemented level	
2982	L	m1	3.4	1.65	1.05	1N 3E 43.5-55 cmbd; below cemented level	
2983	R	m1	3.85	1.9	-	1N 3E 43.5-55 cmbd; below cemented level	worn
2984	L	m1	2.95	1.35	0.55	1N 3E 43.5-55 cmbd; below cemented level	
2985	R	m1	3.55	1.75	1.1	1N 3E 43.5-55 cmbd; below cemented level	
2986	R	m1	3.35	1.6	1.05	1N 3E 43.5-55 cmbd; below cemented level	
2987	R	m1	3.4	1.7	0.8	1N 3E 43.5-55 cmbd; below cemented level	
2988	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	fragment
2989	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2990	L	m1	3.3	1.6	0.9	1N 3E 43.5-55 cmbd; below cemented level	
2991	R	m1	3.3	1.6	1.95	1N 3E 43.5-55 cmbd; below cemented level	
2992	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2993	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	digested
2994	R	m1	2.8	1.35	0.7	1N 3E 43.5-55 cmbd; below cemented level	
2995	R	m1	3.75	1.65	1.95	1N 3E 43.5-55 cmbd; below cemented level	
2996	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2997	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
2998	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
2999	R	m1	2.6	1.25	0.45	1N 3E 43.5-55 cmbd; below cemented level	
3000	L	m1	3.25	1.75	0.75	1N 3E 43.5-55 cmbd; below cemented level	
3001	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	digested
3002	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	digested
3003	R	m1	3.7	1.75	1.6	1N 3E 43.5-55 cmbd; below cemented level	
3004	R	m1	2.7	1.4	1.05	1N 3E 43.5-55 cmbd; below cemented level	
3005	L	m1	3.1	1.6	-	1N 3E 43.5-55 cmbd; below cemented level	damaged
3006	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	damaged
3007	R	m1	3.15	1.8	-	1N 3E 43.5-55 cmbd; below cemented level	worn
3008	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	worn
3009	L	m1	3.3	1.6	0.75	1N 3E 43.5-55 cmbd; below cemented level	
3010	R	m1	2.85	1.45	0.65	1N 3E 43.5-55 cmbd; below cemented level	
3011	L	m1	3.5	1.4	0.85	1N 3E 43.5-55 cmbd; below cemented level	
3012	R	m1	2.9	1.35	0.5	1N 3E 43.5-55 cmbd; below cemented level	
3013	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	worn
3014	R	m1	3.65	1.8	1.0	1N 3E 43.5-55 cmbd; below cemented level	
3015	R	m1	2.65	1.5	1.05	1N 3E 43.5-55 cmbd; below cemented level	
3016	L	m1	2.5	1.1	0.35	1N 3E 43.5-55 cmbd; below cemented level	
3017	R	dentary w/ m1	2.75	1.35	0.8	1N 3E 43.5-55 cmbd; below cemented level	fragment
3018	R	dentary w/ m1	3.55	1.75	1.35	1N 3E 43.5-55 cmbd; below cemented level	fragment
3019	R	m1	2.95	1.4	0.3	1N 3E 43.5-55 cmbd; below cemented level	
3020	L	m1	2.8	1.45	0.85	1N 3E 43.5-55 cmbd; below cemented level	
3021	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	damaged
3022	L	dentary w/ m1-m2	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
3023	R	m1	3.35	1.65	0.9	1N 3E 43.5-55 cmbd; below cemented level	
3024	L	m1	3.0	1.65	0.65	1N 3E 43.5-55 cmbd; below cemented level	
3025	L	m1	3.35	1.65	0.8	1N 3E 43.5-55 cmbd; below cemented level	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3026	R	m1	3.05	1.4	0.75	1N 3E 43.5-55 cmbd; below cemented level	
3027	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	digested
3028	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	worn
3029	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	digested
3030	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	damaged
3031	R	m1	3.5	1.7	1.75	1N 3E 43.5-55 cmbd; below cemented level	
3032	R	m1	3.55	1.8	1.2	1N 3E 43.5-55 cmbd; below cemented level	
3033	L	m1	3.3	1.75	1.05	1N 3E 43.5-55 cmbd; below cemented level	
3034	L	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	worn
3035	R	m1	2.95	1.45	0.7	1N 3E 43.5-55 cmbd; below cemented level	
3036	L	m1	3.8	1.9	1.5	1N 3E 43.5-55 cmbd; below cemented level	
3037	L	m1	2.9	1.35	0.35	1N 3E 43.5-55 cmbd; below cemented level	
3038	R	m1	-	-	-	1N 3E 43.5-55 cmbd; below cemented level	juvenile
96	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
97	R	m1	3.3	1.6	1.55	2N 2-3E 45-60 cmbd	
98	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
99	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested?
100	R	m1	3.3	1.6	1.2	2N 2-3E 45-60 cmbd	
101	R	m1	2.9	1.6	0.8	2N 2-3E 45-60 cmbd	
102	R	m1	3.9	1.9	1.1	2N 2-3E 45-60 cmbd	
103	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
104	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
105	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
106	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
170	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3039	L	m1	3.6	1.85	1.2	2N 2-3E 45-60 cmbd	
3040	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3041	L	m1	3.65	1.8	1.45	2N 2-3E 45-60 cmbd	
3042	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3043	R	m1	3.1	1.45	0.75	2N 2-3E 45-60 cmbd	
3044	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3045	L	m1	3.35	1.6	1.0	2N 2-3E 45-60 cmbd	
3046	R	m1	3.7	1.8	0.1	2N 2-3E 45-60 cmbd	
3047	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3048	R	m1	3.25	1.6	1.1	2N 2-3E 45-60 cmbd	
3049	R	m1	3.35	1.3	1.45	2N 2-3E 45-60 cmbd	
3050	R	m1	3.55	1.6	1.55	2N 2-3E 45-60 cmbd	
3051	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile; fragment
3052	R	m1	3.65	1.75	1.05	2N 2-3E 45-60 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3053	L	m1	3.5	1.6	1.2	2N 2-3E 45-60 cmbd	
3054	L	m1	3.7	1.75	-	2N 2-3E 45-60 cmbd	worn
3055	R	m1	3.3	1.6	1.2	2N 2-3E 45-60 cmbd	
3056	L	m1	3.5	1.75	2.2	2N 2-3E 45-60 cmbd	
3057	L	m1	3.4	1.7	0.25	2N 2-3E 45-60 cmbd	
3058	L	m1	2.75	1.2	0.3	2N 2-3E 45-60 cmbd	
3059	L	m1	3.3	1.6	1.4	2N 2-3E 45-60 cmbd	
3060	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3061	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3062	R	m1	3.2	1.65	1.7	2N 2-3E 45-60 cmbd	
3063	L	m1	3.0	1.55	0.55	2N 2-3E 45-60 cmbd	
3064	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3065	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3066	L	m1	3.05	1.55	1.35	2N 2-3E 45-60 cmbd	
3067	R	m1	3.15	1.7	0.75	2N 2-3E 45-60 cmbd	
3068	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3069	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3070	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3071	R	m1	3.5	1.75	1.1	2N 2-3E 45-60 cmbd	
3072	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3073	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3074	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3075	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3076	L	m1	2.9	1.45	0.4	2N 2-3E 45-60 cmbd	
3077	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3078	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3079	R	m1	3.05	1.5	1.0	2N 2-3E 45-60 cmbd	
3080	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3081	L	m1	3.05	1.45	0.85	2N 2-3E 45-60 cmbd	
3082	L	m1	3.55	1.7	0.95	2N 2-3E 45-60 cmbd	
3083	R	m1	2.9	1.35	0.8	2N 2-3E 45-60 cmbd	
3084	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3085	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3086	R	m1	3.1	1.5	0.8	2N 2-3E 45-60 cmbd	
3087	R	m1	3.8	1.65	1.1	2N 2-3E 45-60 cmbd	illustrate
3088	L	m1	3.55	1.8	1.8	2N 2-3E 45-60 cmbd	
3089	R	m1	3.3	1.65	1.25	2N 2-3E 45-60 cmbd	
3090	R	m1	3.45	1.7	1.4	2N 2-3E 45-60 cmbd	
3091	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3092	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3093	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3094	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3095	L	m1	3.25	1.6	1.25	2N 2-3E 45-60 cmbd	
3096	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3097	R	m1	3.1	1.55	1.2	2N 2-3E 45-60 cmbd	
3098	R	m1	3.05	1.55	0.35	2N 2-3E 45-60 cmbd	
3099	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3100	L	m1	3.5	1.55	1.45	2N 2-3E 45-60 cmbd	
3101	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3102	L	m1	3.45	1.55	2.1	2N 2-3E 45-60 cmbd	
3103	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3104	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3105	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3106	R	m1	3.1	1.4	0.2	2N 2-3E 45-60 cmbd	
3107	R	m1	3.6	1.75	0.5	2N 2-3E 45-60 cmbd	
3108	R	m1	3.6	1.85	1.85	2N 2-3E 45-60 cmbd	
3109	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3110	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3111	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3112	L	m1	3.0	1.55	0.0	2N 2-3E 45-60 cmbd	
3113	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3114	L	m1	3.1	1.5	0.8	2N 2-3E 45-60 cmbd	
3115	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3116	L	m1	3.55	1.65	1.4	2N 2-3E 45-60 cmbd	
3117	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3118	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3119	R	m1	3.75	1.85	1.75	2N 2-3E 45-60 cmbd	
3120	L	m1	3.05	1.5	0.4	2N 2-3E 45-60 cmbd	
3121	R	m1	3.7	1.85	-	2N 2-3E 45-60 cmbd	worn
3122	L	m1	3.0	1.55	1.05	2N 2-3E 45-60 cmbd	
3123	L	m1	3.35	1.65	1.7	2N 2-3E 45-60 cmbd	
3124	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3125	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3126	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3127	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3128	R	m1	3.5	1.75	1.0	2N 2-3E 45-60 cmbd	
3129	L	m1	2.75	1.35	0.3	2N 2-3E 45-60 cmbd	
3130	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3131	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3132	L	m1	3.3	1.75	1.35	2N 2-3E 45-60 cmbd	
3133	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3134	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3135	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3136	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3137	L	m1	3.2	1.7	0.15	2N 2-3E 45-60 cmbd	
3138	L	m1	3.0	1.45	0.45	2N 2-3E 45-60 cmbd	
3139	R	m1	3.0	1.5	1.4	2N 2-3E 45-60 cmbd	
3140	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3141	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3142	R	m1	3.3	1.6	0.75	2N 2-3E 45-60 cmbd	
3143	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3144	L	m1	3.2	1.6	1.75	2N 2-3E 45-60 cmbd	
3145	L	m1	3.5	1.85	0.85	2N 2-3E 45-60 cmbd	
3146	L	m1	3.45	1.85	0.55	2N 2-3E 45-60 cmbd	
3147	L	m1	2.55	1.25	0.35	2N 2-3E 45-60 cmbd	
3148	R	m1	3.0	1.45	0.75	2N 2-3E 45-60 cmbd	
3149	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3150	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3151	R	m1	3.1	1.5	1.3	2N 2-3E 45-60 cmbd	
3152	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3153	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3154	L	m1	2.95	1.5	0.5	2N 2-3E 45-60 cmbd	
3155	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3156	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3157	L	m1	3.0	1.45	1.15	2N 2-3E 45-60 cmbd	
3158	R	m1	3.75	1.75	1.15	2N 2-3E 45-60 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3159	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3160	R	m1	3.9	1.9	1.4	2N 2-3E 45-60 cmbd	
3161	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3162	L	m1	2.95	1.4	0.25	2N 2-3E 45-60 cmbd	
3163	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3164	R	m1	3.3	1.6	1.2	2N 2-3E 45-60 cmbd	
3165	R	m1	3.15	1.65	1.0	2N 2-3E 45-60 cmbd	
3166	R	m1	3.4	1.65	1.1	2N 2-3E 45-60 cmbd	
3167	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3168	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3169	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3170	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3171	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3172	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3173	L	m1	3.9	1.8	1.9	2N 2-3E 45-60 cmbd	
3174	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3175	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3176	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3177	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3178	R	m1	3.05	1.6	0.7	2N 2-3E 45-60 cmbd	
3179	R	m1	3.25	1.5	0.35	2N 2-3E 45-60 cmbd	
3180	L	m1	2.4	1.3	0.1	2N 2-3E 45-60 cmbd	
3181	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3182	R	m1	2.85	1.35	1.05	2N 2-3E 45-60 cmbd	
3183	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3184	L	m1	2.75	1.35	0.35	2N 2-3E 45-60 cmbd	
3185	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3186	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3187	L	m1	3.75	1.65	1.5	2N 2-3E 45-60 cmbd	
3188	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3189	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3190	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3191	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3192	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3193	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3194	R	m1	2.8	1.4	0.25	2N 2-3E 45-60 cmbd	
3195	R	m1	3.1	1.6	0.35	2N 2-3E 45-60 cmbd	
3196	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3197	R	m1	3.35	1.6	1.75	2N 2-3E 45-60 cmbd	
3198	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3199	L	m1	3.15	1.75	0.45	2N 2-3E 45-60 cmbd	
3200	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3201	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3202	L	m1	3.4	1.8	1.2	2N 2-3E 45-60 cmbd	
3203	L	m1	3.45	1.65	1.2	2N 2-3E 45-60 cmbd	
3204	R	m1	3.5	1.65	0.9	2N 2-3E 45-60 cmbd	
3205	L	m1	3.5	1.65	1.25	2N 2-3E 45-60 cmbd	
3206	R	m1	3.45	1.7	1.1	2N 2-3E 45-60 cmbd	
3207	L	m1	2.8	1.3	1.1	2N 2-3E 45-60 cmbd	
3208	R	m1	3.1	1.6	1.15	2N 2-3E 45-60 cmbd	
3209	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3210	R	m1	3.45	1.6	1.3	2N 2-3E 45-60 cmbd	
3211	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3212	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3213	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3214	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3215	L	m1	3.2	1.55	1.1	2N 2-3E 45-60 cmbd	
3216	L	m1	3.65	1.8	-	2N 2-3E 45-60 cmbd	worn
3217	L	m1	3.7	1.85	1.7	2N 2-3E 45-60 cmbd	
3218	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3219	R	m1	2.75	1.4	0.75	2N 2-3E 45-60 cmbd	
3220	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3221	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3222	L	m1	3.2	1.5	0.1	2N 2-3E 45-60 cmbd	
3223	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3224	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3225	L	m1	3.1	1.5	1.0	2N 2-3E 45-60 cmbd	
3226	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3227	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3228	L	m1	2.75	1.45	1.05	2N 2-3E 45-60 cmbd	
3229	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged; digested
3230	L	m1	3.4	1.65	1.15	2N 2-3E 45-60 cmbd	
3231	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3232	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3233	R	m1	3.25	1.65	1.6	2N 2-3E 45-60 cmbd	
3234	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3235	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3236	L	m1	3.6	2.05	1.1	2N 2-3E 45-60 cmbd	
3237	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3238	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3239	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3240	R	m1	2.75	1.35	0.5	2N 2-3E 45-60 cmbd	
3241	L	m1	3.25	1.55	1.4	2N 2-3E 45-60 cmbd	
3242	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3243	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3244	R	m1	3.0	1.5	0.15	2N 2-3E 45-60 cmbd	
3245	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3246	L	m1	2.8	1.3	1.0	2N 2-3E 45-60 cmbd	
3247	L	m1	3.15	1.6	0.3	2N 2-3E 45-60 cmbd	
3248	L	m1	2.85	1.3	0.5	2N 2-3E 45-60 cmbd	
3249	R	m1	2.55	1.2	0.45	2N 2-3E 45-60 cmbd	
3250	R	m1	2.85	1.35	0.3	2N 2-3E 45-60 cmbd	
3251	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3252	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3253	L	m1	3.65	1.8	1.1	2N 2-3E 45-60 cmbd	
3254	L	m1	3.1	1.6	0.9	2N 2-3E 45-60 cmbd	
3255	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3256	L	m1	3.3	1.55	1.4	2N 2-3E 45-60 cmbd	
3257	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3258	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3259	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3260	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3261	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3262	R	m1	3.6	1.85	1.5	2N 2-3E 45-60 cmbd	
3263	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3264	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3265	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3266	L	m1	2.9	1.5	0.35	2N 2-3E 45-60 cmbd	
3267	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3268	R	m1	3.05	1.5	1.1	2N 2-3E 45-60 cmbd	
3269	R	m1	3.5	1.75	0.15	2N 2-3E 45-60 cmbd	
3270	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3271	R	m1	-	-	-	2N 2-3E 45-60 cmbd	poor preservation
3272	L	m1	2.95	1.5	0.35	2N 2-3E 45-60 cmbd	
3273	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3274	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3275	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3276	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3277	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3278	R	m1	3.35	1.75	1.5	2N 2-3E 45-60 cmbd	
3279	L	m1	2.95	1.5	0.7	2N 2-3E 45-60 cmbd	
3280	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3281	L	m1	3.05	1.5	0.55	2N 2-3E 45-60 cmbd	
3282	L	m1	3.0	1.5	0.85	2N 2-3E 45-60 cmbd	
3283	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3284	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3285	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3286	L	m1	3.6	1.8	2.25	2N 2-3E 45-60 cmbd	
3287	R	m1	3.6	1.8	-	2N 2-3E 45-60 cmbd	worn
3288	R	m1	3.5	2.0	1.3	2N 2-3E 45-60 cmbd	
3289	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3290	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3291	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3292	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3293	R	m1	3.05	1.45	0.55	2N 2-3E 45-60 cmbd	
3294	R	m1	3.45	1.75	0.75	2N 2-3E 45-60 cmbd	
3295	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3296	R	m1	3.15	1.6	0.8	2N 2-3E 45-60 cmbd	
3297	R	m1	3.5	1.7	1.8	2N 2-3E 45-60 cmbd	
3298	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3299	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3300	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3301	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3302	R	m1	3.15	1.6	1.05	2N 2-3E 45-60 cmbd	
3303	L	m1	3.55	1.95	1.75	2N 2-3E 45-60 cmbd	
3304	L	m1	3.5	-	-	2N 2-3E 45-60 cmbd	damaged
3305	L	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3306	R	m1	3.1	1.55	1.4	2N 2-3E 45-60 cmbd	
3307	R	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3308	R	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3309	L	m1	3.05	1.5	0.75	2N 2-3E 45-60 cmbd	
3310	L	m1	-	-	-	2N 2-3E 45-60 cmbd	worn
3311	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3312	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3313	L	m1	3.4	1.7	0.85	2N 2-3E 45-60 cmbd	
3314	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3315	R	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3316	R	m1	3.0	1.4	0.35	2N 2-3E 45-60 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3317	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3318	R	m1	3.55	1.75	-	2N 2-3E 45-60 cmbd	damaged
3319	L	m1	2.8	1.25	0.4	2N 2-3E 45-60 cmbd	
3320	R	m1	3.2	1.6	1.5	2N 2-3E 45-60 cmbd	
3321	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3322	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3323	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3324	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3325	L	m1	3.0	1.5	1.2	2N 2-3E 45-60 cmbd	
3326	L	m1	3.4	1.75	0.6	2N 2-3E 45-60 cmbd	
3327	L	m1	3.55	1.65	2.0	2N 2-3E 45-60 cmbd	
3328	R	m1	3.55	1.65	1.4	2N 2-3E 45-60 cmbd	
3329	R	m1	-	-	-	2N 2-3E 45-60 cmbd	damaged
3330	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3331	R	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3332	L	m1	-	-	-	2N 2-3E 45-60 cmbd	digested
3333	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3334	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3335	R	m1	3.8	1.9	-	2N 2-3E 45-60 cmbd	worn
3336	L	m1	-	-	-	2N 2-3E 45-60 cmbd	fragment
3337	L	m1	-	-	-	2N 2-3E 45-60 cmbd	juvenile
3338	L	m1	3.3	1.65	0.8	2N 2-3E 45-60 cmbd	
3339	L	dentary w/ m1-m2	2.95	1.5	0.3	2N 2-3E 45-60 cmbd	
3340	R	dentary w/ i1, m1-m2	-	-	-	2N 2-3E 45-60 cmbd	worn
3341	L	m1	3.65	1.75	-	2N 2-3E 45-60 cmbd	
3342	R	m1	2.75	1.45	0.6	2N 2-3E 45-60 cmbd	
3343	R	m1	2.9	1.45	0.8	2N 2-3E 45-60 cmbd	
3344	L	m1	-	-	-	1N 2E 50-55 cmbd	worn
3345	L	m1	-	-	-	1N 2E 50-55 cmbd	juvenile
3346	L	m1	3.05	1.45	0.35	1N 2E 50-55 cmbd	
3347	R	m1	-	-	-	1N 2E 50-55 cmbd	juvenile
3348	L	m1	2.9	1.5	0.7	1N 2E 50-55 cmbd	
3349	L	m1	-	-	-	1N 2E 50-55 cmbd	digested
3350	R	m1	-	-	-	1N 2E 50-55 cmbd	fragment
3351	R	m1	2.85	1.5	0.1	1N 2E 50-55 cmbd	
3352	L	m1	2.75	1.4	0.35	1N 2E 50-55 cmbd	
3353	L	m1	-	-	-	1N 2E 50-55 cmbd	worn
3354	L	m1	2.75	1.3	0.65	1N 2E 50-55 cmbd	
3355	R	m1	3.0	1.45	0.4	1N 2E 50-55 cmbd	
3356	R	m1	3.7	1.8	1.8	1N 2E 50-55 cmbd	
3357	R	m1	3.05	1.45	1.05	1N 2E 50-55 cmbd	
3358	L	m1	3.3	1.65	0.9	1N 2E 50-55 cmbd	
3359	L	m1	-	-	-	1N 2E 50-55 cmbd	damaged
3360	L	m1	3.6	1.95	1.25	1N 2E 50-55 cmbd	
3361	L	m1	-	-	-	1N 2E 50-55 cmbd	damaged
3362	R	m1	2.65	1.5	1.25	1N 2E 50-55 cmbd	
3363	L	m1	3.05	1.45	0.05	1N 2E 50-55 cmbd	
3364	L	m1	3.2	1.4	0.75	1N 2E 50-55 cmbd	
3365	R	m1	3.2	1.6	0.75	1N 2E 50-55 cmbd	
3366	L	m1	-	-	-	1N 2E 50-55 cmbd	damaged
3367	L	m1	3.35	1.65	1.85	1N 2E 50-55 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3368	L	m1	3.75	1.8	1.25	1N 2E 50-55 cmbd	
3369	L	m1	2.85	1.4	0.45	1N 2E 50-55 cmbd	
3370	L	m1	-	-	-	1N 2E 50-55 cmbd	juvenile
3371	L	m1	-	-	-	1N 2E 50-55 cmbd	digested
3372	L	m1	-	-	-	1N 2E 50-55 cmbd	digested
3373	L	m1	3.3	1.6	1.3	1N 2E 50-55 cmbd	
3374	R	m1	3.5	1.7	1.75	1N 2E 50-55 cmbd	
3375	R	m1	2.9	1.45	0.7	1N 2E 50-55 cmbd	
3376	L	m1	2.85	1.45	0.4	1N 2E 50-55 cmbd	
3377	L	m1	3.3	1.6	0.45	1N 2E 50-55 cmbd	
3378	L	m1	-	-	-	1N 2E 50-55 cmbd	juvenile
3379	R	m1	3.7	1.4	1.5	1N 2E 50-55 cmbd	
3380	L	m1	-	-	-	1N 2E 50-55 cmbd	digested
3381	R	m1	-	-	-	1N 2E 50-55 cmbd	worn
3382	R	m1	-	-	-	1N 2E 50-55 cmbd	digested
3383	R	m1	-	-	-	1N 2E 55-60 cmbd	worn
3384	R	m1	-	-	-	1N 2E 55-60 cmbd	digested
3385	R	m1	3.5	1.8	0.95	1N 2E 55-60 cmbd	
3386	R	m1	3.4	1.65	1.4	1N 2E 55-60 cmbd	
3387	L	m1	3.3	1.65	0.1	1N 2E 55-60 cmbd	
3388	L	m1	3.25	1.7	0.6	1N 2E 55-60 cmbd	
3389	L	m1	-	-	-	1N 2E 55-60 cmbd	damaged
3390	R	m1	-	-	-	1N 2E 55-60 cmbd	worn
3391	R	m1	3.2	1.65	1.5	1N 2E 55-60 cmbd	
3392	R	m1	-	-	-	1N 2E 55-60 cmbd	digested
3393	R	m1	3.55	1.65	1.55	1N 2E 55-60 cmbd	
3394	R	m1	-	-	-	1N 2E 55-60 cmbd	fragment
3395	L	m1	-	-	-	1N 2E 55-60 cmbd	juvenile
3396	R	m1	-	-	-	1N 2E 55-60 cmbd	worn
3397	R	m1	-	-	-	1N 2E 55-60 cmbd	damaged
3398	L	m1	-	-	-	1N 2E 55-60 cmbd	worn
3399	L	m1	2.9	1.35	0.75	1N 2E 55-60 cmbd	
3400	R	m1	-	-	-	1N 2E 55-60 cmbd	digested
3401	L	m1	2.9	1.45	0.6	1N 2E 55-60 cmbd	
3402	R	m1	3.45	1.6	1.1	1N 2E 55-60 cmbd	
3403	R	m1	-	-	-	1N 2E 55-60 cmbd	worn
3404	L	m1	-	-	-	1N 2E 55-60 cmbd	worn
3405	L	m1	2.75	-	-	1N 2E 55-60 cmbd	digested
3406	R	m1	3.35	1.45	0.7	1N 2E 55-60 cmbd	
3407	R	m1	-	-	-	1N 2E 55-60 cmbd	juvenile
3408	R	m1	2.45	1.3	0.75	1N 2E 55-60 cmbd	
3409	L	m1	3.25	1.7	0.4	1N 2E 55-60 cmbd	
3410	R	m1	3.35	1.6	0.85	1N 2E 55-60 cmbd	
3411	R	m1	-	-	-	1N 3E 55-60 cmbd	fragment
3412	R	m1	3.3	1.65	1.0	1N 3E 55-60 cmbd	
3413	L	m1	-	-	-	1N 3E 55-60 cmbd	juvenile
3414	L	m1	3.5	1.65	1.25	1N 3E 55-60 cmbd	digested
3415	R	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3416	R	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3417	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3418	L	m1	3.35	1.7	1.7	1N 3E 55-60 cmbd	
3419	R	m1	3.1	1.5	0.3	1N 3E 55-60 cmbd	
3420	R	m1	-	-	-	1N 3E 55-60 cmbd	fragment

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3421	R	m1	-	-	-	1N 3E 55-60 cmbd	juvenile; digested
3422	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3423	L	m1	-	-	-	1N 3E 55-60 cmbd	digested
3424	L	m1	-	-	-	1N 3E 55-60 cmbd	juvenile
3425	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3426	L	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3427	L	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3428	L	m1	-	-	-	1N 3E 55-60 cmbd	digested
3429	L	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3430	L	m1	3.6	1.65	1.4	1N 3E 55-60 cmbd	
3431	L	m1	-	-	-	1N 3E 55-60 cmbd	juvenile; digested
3432	R	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3433	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3434	R	m1	3.15	1.45	0.7	1N 3E 55-60 cmbd	
3435	R	m1	-	-	-	1N 3E 55-60 cmbd	fragment
3436	L	m1	-	-	-	1N 3E 55-60 cmbd	digested
3437	R	m1	-	-	-	1N 3E 55-60 cmbd	digested
3438	L	m1	-	-	-	1N 3E 55-60 cmbd	juvenile
3439	L	m1	2.95	1.5	0.45	1N 3E 55-60 cmbd	
3440	R	m1	3.4	1.85	0.6	1N 3E 55-60 cmbd	
3441	L	m1	3.75	1.85	1.25	1N 3E 55-60 cmbd	
3442	L	m1	3.65	2.05	1.3	1N 3E 55-60 cmbd	
3443	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3444	R	m1	3.55	1.65	1.55	1N 3E 55-60 cmbd	
3445	L	m1	-	-	-	1N 3E 55-60 cmbd	digested
3446	R	m1	2.95	1.65	0.65	1N 3E 55-60 cmbd	
3447	R	m1	3.3	1.55	1.6	1N 3E 55-60 cmbd	
3448	L	m1	2.95	1.6	0.3	1N 3E 55-60 cmbd	
3449	R	m1	2.95	1.4	0.4	1N 3E 55-60 cmbd	
3450	R	m1	3.45	1.75	1.15	1N 3E 55-60 cmbd	
3451	L	m1	-	-	-	1N 3E 55-60 cmbd	worn
3452	L	m1	-	-	-	1N 3E 55-60 cmbd	digested
3453	R	m1	-	-	-	1N 3E 55-60 cmbd	damaged
3454	L	m1	3.85	1.8	1.6	1N 3E 55-60 cmbd	
3455	R	m1	-	-	-	1N 3E 55-60 cmbd	worn
3456	R	m1	3.45	1.75	1.1	1N 3E 55-60 cmbd	
3457	L	m1	3.5	1.75	1.0	1N 3E 55-60 cmbd	
3458	R	m1	-	-	-	1N 3E 55-60 cmbd	juvenile
3459	L	m1	3.2	1.55	1.05	1N 3E 55-60 cmbd	digested
3460	R	m1	2.8	1.4	0.8	1N 3E 55-60 cmbd	
3461	R	m1	2.55	1.3	0.4	1N 3E 55-60 cmbd	
3462	L	m1	3.25	1.6	1.25	1N 3E 55-60 cmbd	
3463	R	dentary w/ i1, m1	3.7	1.8	1.65	1N 3E 55-60 cmbd	
3464	L	m1	-	-	-	1N 2E 60-65 cmbd	digested
3465	R	m1	-	-	-	1N 2E 60-65 cmbd	digested
3466	L	m1	3.65	1.65	0.85	1N 2E 60-65 cmbd	
3467	R	m1	3.25	1.7	0.7	1N 2E 60-65 cmbd	
3468	R	dentary w/ m1-m2	-	-	-	1N 2E 60-65 cmbd	fragment; worn
3469	L	m1	-	-	-	1N 2E 60-65 cmbd	digested
3470	R	m1	-	-	-	1N 2E 60-65 cmbd	fragment
3471	L	m1	-	-	-	1N 2E 60-65 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3472	R	m1	2.9	1.45	0.5	1N 2E 60-65 cmbd	
3473	R	m1	3.2	1.4	1.4	1N 2E 60-65 cmbd	
3474	R	m1	3.1	1.5	0.7	1N 2E 60-65 cmbd	
3475	R	m1	-	-	-	1N 2E 60-65 cmbd	juvenile
3476	R	m1	-	-	-	1N 2E 60-65 cmbd	worn
3477	R	m1	-	-	-	1N 2E 60-65 cmbd	digested
3478	R	m1	-	-	-	1N 2E 60-65 cmbd	digested
3479	L	m1	-	-	-	1N 2E 60-65 cmbd	digested
3480	R	m1	3.45	1.6	0.75	1N 2E 60-65 cmbd	
3481	R	m1	3.55	1.75	0.85	1N 2E 60-65 cmbd	
3482	L	m1	-	-	-	1N 2E 60-65 cmbd	digested
3483	R	m1	-	-	-	1N 2E 60-65 cmbd	juvenile
3484	R	m1	3.6	1.8	2.1	1N 2E 60-65 cmbd	
3485	R	m1	-	-	-	1N 2E 60-65 cmbd	digested
3486	L	m1	-	-	-	1N 2E 60-65 cmbd	juvenile; digested
3487	R	m1	3.15	1.7	1.35	1N 2E 60-65 cmbd	
3488	L	m1	3.6	1.75	1.0	1N 2E 60-65 cmbd	
3489	R	m1	3.3	1.7	1.8	1N 2E 60-65 cmbd	
3490	R	m1	-	-	-	1N 2E 60-65 cmbd	juvenile
3491	R	m1	3.4	1.55	0.8	1N 2E 60-65 cmbd	
3492	L	m1	-	-	-	1N 2E 60-65 cmbd	juvenile
3493	L	m1	2.95	1.4	0.25	1N 2E 60-65 cmbd	
3494	R	m1	-	-	-	1N 2E 60-65 cmbd	juvenile
3495	R	m1	2.9	1.5	0.9	1N 2E 60-65 cmbd	
3496	L	m1	-	-	-	1N 2E 60-65 cmbd	digested
3497	R	m1	-	-	-	1N 2E 60-65 cmbd	digested
3498	L	dentary w/ m1	-	-	-	1N 2E 60-65 cmbd	juvenile; fragment
3499	L	m1	3.75	1.85	1.05	1N 2E 60-65 cmbd	
3500	R	m1	3.3	1.75	0.65	1N 2E 60-65 cmbd	
3501	R	m1	3.1	1.65	1.3	1N 2E 60-65 cmbd	
3502	L	m1	3.1	1.6	0.6	1N 2E 60-65 cmbd	
3503	L	m1	2.9	1.5	0.6	1N 2E 60-65 cmbd	
3504	L	m1	2.85	1.55	0.5	1N 2E 60-65 cmbd	
3505	R	m1	2.85	1.5	0.6	1N 2E 60-65 cmbd	
3506	R	m1	3.7	1.8	-	1N 2E 60-65 cmbd	worn
1587	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
1601	R	m1	-	-	-	1N 3E 60-65 cmbd	fragment
3507	R	m1	3.4	1.35	0.85	1N 3E 60-65 cmbd	
3508	L	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3509	R	m1	-	-	-	1N 3E 60-65 cmbd	worn
3510	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3511	R	m1	2.95	1.55	0.7	1N 3E 60-65 cmbd	
3512	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3513	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3514	L	m1	3.55	1.7	1.05	1N 3E 60-65 cmbd	
3515	L	m1	2.85	1.4	0.9	1N 3E 60-65 cmbd	
3516	R	m1	-	-	-	1N 3E 60-65 cmbd	worn
3517	L	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3518	R	m1	3.3	1.8	0.8	1N 3E 60-65 cmbd	
3519	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3520	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3521	R	m1	-	-	-	1N 3E 60-65 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3522	L	m1	-	-	-	1N 3E 60-65 cmbd	worn
3523	L	m1	3.8	1.8	1.15	1N 3E 60-65 cmbd	
3524	L	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3525	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3526	L	m1	-	-	-	1N 3E 60-65 cmbd	digested
3527	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3528	L	m1	-	-	-	1N 3E 60-65 cmbd	worn
3529	R	m1	-	-	-	1N 3E 60-65 cmbd	worn
3530	L	m1	2.8	1.45	0.45	1N 3E 60-65 cmbd	
3531	L	m1	3.8	1.75	1.2	1N 3E 60-65 cmbd	
3532	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3533	R	m1	3.45	1.8	0.75	1N 3E 60-65 cmbd	
3534	R	m1	3.9	1.8	0.8	1N 3E 60-65 cmbd	
3535	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile; digested
3536	R	dentary w/ m1	-	-	-	1N 3E 60-65 cmbd	fragment; worn
3537	R	m1	-	-	-	1N 3E 60-65 cmbd	digested?
3538	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3539	L	m1	-	-	-	1N 3E 60-65 cmbd	digested?
3540	L	m1	3.55	1.7	-	1N 3E 60-65 cmbd	damaged?
3541	L	m1	3.4	1.6	0.65	1N 3E 60-65 cmbd	
3542	L	m1	3.5	1.75	0.9	1N 3E 60-65 cmbd	
3543	L	m1	3.3	1.5	1.1	1N 3E 60-65 cmbd	
3544	R	m1	-	-	-	1N 3E 60-65 cmbd	worn
3545	R	m1	3.8	1.75	0.4	1N 3E 60-65 cmbd	
3546	L	m1	2.9	1.35	1.0	1N 3E 60-65 cmbd	
3547	R	m1	3.3	1.65	1.1	1N 3E 60-65 cmbd	
3548	L?	m1	-	-	-	1N 3E 60-65 cmbd	worn
3549	R	m1	3.2	1.6	1.2	1N 3E 60-65 cmbd	
3550	R	m1	3.55	1.75	0.95	1N 3E 60-65 cmbd	
3551	L	m1	2.75	1.3	0.45	1N 3E 60-65 cmbd	
3552	L	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3553	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3554	R	dentary w/ m1	-	-	-	1N 3E 60-65 cmbd	digested; worn
3555	R	m1	3.4	1.8	0.8	1N 3E 60-65 cmbd	
3556	R	m1	-	-	-	1N 3E 60-65 cmbd	worn
3557	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3558	R	m1	3.7	1.85	1.0	1N 3E 60-65 cmbd	
3559	R	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3560	L	m1	3.15	1.6	1.2	1N 3E 60-65 cmbd	
3561	R	m1	-	-	-	1N 3E 60-65 cmbd	fragment
3562	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3563	L	m1	-	-	-	1N 3E 60-65 cmbd	
3564	L	m1	3.55	1.75	0.85	1N 3E 60-65 cmbd	
3565	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3566	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3567	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3568	R	m1	3.6	1.7	1.45	1N 3E 60-65 cmbd	
3569	L	m1	3.35	1.6	1.3	1N 3E 60-65 cmbd	
3570	R	m1	-	-	-	1N 3E 60-65 cmbd	damaged
3571	R	m1	3.7	1.75	0.5	1N 3E 60-65 cmbd	
3572	L	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3573	L	m1	-	-	-	1N 3E 60-65 cmbd	digested; damaged

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3574	L	m1	-	-	-	1N 3E 60-65 cmbd	fragment
3575	L	m1	-	-	-	1N 3E 60-65 cmbd	damaged; worn
3576	R	m1	3.4	1.7	0.65	1N 3E 60-65 cmbd	
3577	L	m1	-	-	-	1N 3E 60-65 cmbd	digested
3578	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3579	R	m1	-	-	-	1N 3E 60-65 cmbd	juvenile
3580	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3581	R	m1	-	-	-	1N 3E 60-65 cmbd	digested
3582	L	m1	-	-	-	1N 3E 60-65 cmbd	digested
3583	L	m1	3.4	1.65	0.5	1N 3E 60-65 cmbd	
3584	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3585	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3586	L	m1	3.15	1.5	1.05	2N 2-3E 60-65 cmbd	
3587	L	m1	3.1	1.45	1.0	2N 2-3E 60-65 cmbd	
3588	L	m1	3.25	1.6	1.3	2N 2-3E 60-65 cmbd	
3589	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3590	L	m1	3.4	1.8	0.8	2N 2-3E 60-65 cmbd	
3591	L	m1	3.4	1.7	1.25	2N 2-3E 60-65 cmbd	
3592	R	m1	-	-	-	2N 2-3E 60-65 cmbd	worn; damaged
3593	L	m1	3.35	1.6	1.75	2N 2-3E 60-65 cmbd	
3594	L	m1	3.3	1.6	1.45	2N 2-3E 60-65 cmbd	
3595	L	m1	3.1	1.7	0.5	2N 2-3E 60-65 cmbd	
3596	L	m1	3.05	1.5	1.4	2N 2-3E 60-65 cmbd	
3597	R	m1	3.3	1.65	1.3	2N 2-3E 60-65 cmbd	
3598	R	m1	-	-	-	2N 2-3E 60-65 cmbd	fragment
3599	L	m1	3.7	1.75	0.75	2N 2-3E 60-65 cmbd	
3600	L	m1	3.05	1.55	1.55	2N 2-3E 60-65 cmbd	
3601	L	m1	2.95	1.5	0.55	2N 2-3E 60-65 cmbd	
3602	R	m1	-	-	-	2N 2-3E 60-65 cmbd	digested
3603	R	m1	2.95	1.6	0.3	2N 2-3E 60-65 cmbd	
3604	R	m1	3.85	1.8	1.75	2N 2-3E 60-65 cmbd	
3605	L	m1	3.1	1.6	1.15	2N 2-3E 60-65 cmbd	
3606	R	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3607	R	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3608	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3609	R	m1	3.1	1.4	0.55	2N 2-3E 60-65 cmbd	
3610	R	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3611	R	m1	-	-	-	2N 2-3E 60-65 cmbd	fragment
3612	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile; digested
3613	L	m1	2.95	1.45	0.55	2N 2-3E 60-65 cmbd	
3614	R	m1	3.1	1.5	0.9	2N 2-3E 60-65 cmbd	
3615	L	m1	3.45	1.7	1.05	2N 2-3E 60-65 cmbd	
3616	R	m1	2.75	1.45	0.45	2N 2-3E 60-65 cmbd	
3617	R	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3618	L	m1	3.25	1.65	1.1	2N 2-3E 60-65 cmbd	
3619	R	m1	3.3	1.7	0.7	2N 2-3E 60-65 cmbd	
3620	R	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3621	L	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3622	L	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3623	R	m1	-	-	-	2N 2-3E 60-65 cmbd	fragment
3624	L	m1	3.5	1.75	1.4	2N 2-3E 60-65 cmbd	
3625	R	m1	-	-	-	2N 2-3E 60-65 cmbd	digested
3626	L	m1	3.3	1.65	1.35	2N 2-3E 60-65 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3627	L	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3628	R	m1	2.7	1.3	1.15	2N 2-3E 60-65 cmbd	
3629	L	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3630	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3631	R	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3632	R	m1	4.0	1.9	-	2N 2-3E 60-65 cmbd	worn
3633	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3634	L	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3635	L	dentary w/ m1	2.65	1.25	0.45	2N 2-3E 60-65 cmbd	fragment
3636	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3637	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3638	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3639	R	m1	3.0	1.65	0.8	2N 2-3E 60-65 cmbd	
3640	L	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3641	R	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3642	L	m1	3.35	1.6	1.15	2N 2-3E 60-65 cmbd	digested
3643	R	m1	2.8	1.4	0.5	2N 2-3E 60-65 cmbd	
3644	R	m1	-	-	-	2N 2-3E 60-65 cmbd	damaged
3645	L	m1	3.15	1.7	0.55	2N 2-3E 60-65 cmbd	
3646	L	m1	-	-	-	2N 2-3E 60-65 cmbd	digested
3647	R	m1	3.3	1.6	0.7	2N 2-3E 60-65 cmbd	
3648	R	m1	3.2	1.6	1.55	2N 2-3E 60-65 cmbd	
3649	R	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3650	L	m1	3.45	1.75	-	2N 2-3E 60-65 cmbd	worn
3651	R	m1	2.75	1.35	0.0	2N 2-3E 60-65 cmbd	
3652	L	m1	-	-	-	2N 2-3E 60-65 cmbd	juvenile
3653	R	m1	2.85	1.55	1.4	2N 2-3E 60-65 cmbd	
3654	L	dentary w/ m1	-	-	-	2N 2-3E 60-65 cmbd	parial; worn
3655	R	m1	2.6	1.3	0.55	2N 2-3E 60-65 cmbd	
3656	R	m1	3.0	1.4	0.75	2N 2-3E 60-65 cmbd	
3657	L	m1	2.75	1.5	0.3	2N 2-3E 60-65 cmbd	
3658	R	m1	3.4	1.65	1.55	2N 2-3E 60-65 cmbd	
3659	R	dentary w/ m1-m3	-	-	-	2N 2-3E 60-65 cmbd	worn
3660	R	m1	3.0	1.35	1.4	2N 2-3E 60-65 cmbd	
3661	R	m1	-	-	-	2N 2-3E 60-65 cmbd	worn
3662	L	m1	3.25	1.5	1.25	2N 2-3E 60-65 cmbd	
3663	L	m1	2.65	1.25	0.45	1N 2E 65-70 cmbd	
3664	R	m1	-	-	-	1N 2E 65-70 cmbd	damaged
3665	L	m1	-	-	-	1N 2E 65-70 cmbd	fragment
3666	L	m1	-	-	-	1N 2E 65-70 cmbd	damaged
3667	R	m1	3.0	1.45	1.05	1N 2E 65-70 cmbd	
3668	R	m1	-	-	-	1N 2E 65-70 cmbd	worn
3669	L	m1	3.55	1.75	1.4	1N 2E 65-70 cmbd	
3670	R	m1	3.5	1.7	1.2	1N 2E 65-70 cmbd	
3671	L	m1	3.25	1.65	2.0	1N 2E 65-70 cmbd	
3672	R	m1	2.85	1.35	0.5	1N 2E 65-70 cmbd	
3673	L	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3674	L	m1	2.8	1.45	0.45	1N 2E 65-70 cmbd	
3675	R	m1	3.4	1.8	0.9	1N 2E 65-70 cmbd	
3676	R	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3677	R	m1	3.6	2.95	0.15	1N 2E 65-70 cmbd	
3678	R	m1	-	-	-	1N 2E 65-70 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3679	R	m1	3.45	1.7	0.85	1N 2E 65-70 cmbd	
3680	L	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3681	R	m1	3.35	1.75	0.95	1N 2E 65-70 cmbd	
3682	R	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3683	L	m1	3.3	1.75	1.55	1N 2E 65-70 cmbd	
3684	R	m1	3.25	1.55	1.55	1N 2E 65-70 cmbd	
3685	R	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3686	L	m1	3.5	1.8	1.3	1N 2E 65-70 cmbd	
3687	L	m1	-	-	-	1N 2E 65-70 cmbd	worn
3688	R	m1	-	-	-	1N 2E 65-70 cmbd	juvenile
3689	R	m1	3.35	1.7	0.8	1N 2E 65-70 cmbd	
3690	R	m1	-	-	-	1N 2E 65-70 cmbd	worn
3691	L	m1	3.0	1.55	0.6	1N 2E 65-70 cmbd	
3692	R	m1	-	-	-	1N 2E 65-70 cmbd	digested
3693	L	dentary w/ i1, m1-m2	3.7	1.8	0.9	1N 2E 65-70 cmbd	partial
3694	R	m1	2.8	1.5	0.4	1N 2E 65-70 cmbd	
1336	R	m1	-	-	-	1N 3E 65-70 cmbd	fragment
1519	R	m1	3.6	1.65	1.7	1N 3E 65-70 cmbd	
1540	L	m1	3.5	1.7	0.75	1N 3E 65-70 cmbd	
1546	L	m1	3.05	1.6	0.45	1N 3E 65-70 cmbd	
1549	R	m1	-	-	-	1N 3E 65-70 cmbd	digested
1550	L	m1	-	-	-	1N 3E 65-70 cmbd	damaged
1553	R	dentary w/ m1	3.55	1.9	1.3	1N 3E 65-70 cmbd	fragment
1554	L	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3695	L	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3696	L	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3697	L	m1	3.65	1.8	1.0	1N 3E 65-70 cmbd	
3698	R	m1	3.5	1.8	1.3	1N 3E 65-70 cmbd	
3699	R	m1	3.15	1.55	1.05	1N 3E 65-70 cmbd	
3700	R	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3701	R	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3702	L	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3703	R	m1	-	-	-	1N 3E 65-70 cmbd	worn
3704	L	m1	-	-	-	1N 3E 65-70 cmbd	digested
3705	R	m1	-	-	-	1N 3E 65-70 cmbd	worn
3706	R	m1	-	-	-	1N 3E 65-70 cmbd	worn
3707	R	m1	3.5	1.85	1.2	1N 3E 65-70 cmbd	
3708	L	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3709	R	m1	3.2	1.75	1.05	1N 3E 65-70 cmbd	
3710	R	m1	3.45	1.75	1.25	1N 3E 65-70 cmbd	
3711	R	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3712	L	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3713	R	m1	3.65	1.75	1.1	1N 3E 65-70 cmbd	
3714	R	dentary w/ i1 (broken); m1	3.45	1.8	0.6	1N 3E 65-70 cmbd	partial
3715	R	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3716	R	m1	2.85	1.4	0.5	1N 3E 65-70 cmbd	
3717	L	m1	-	-	-	1N 3E 65-70 cmbd	worn
3718	R	m1	2.95	1.55	1.5	1N 3E 65-70 cmbd	
3719	R	m1	3.1	1.6	0.85	1N 3E 65-70 cmbd	
3720	R	dentary w/ m1	-	-	-	1N 3E 65-70 cmbd	worn
3721	L	m1	-	-	-	1N 3E 65-70 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3722	R	m1	-	-	-	1N 3E 65-70 cmbd	worn
3723	L	m1	3.5	1.8	2.6	1N 3E 65-70 cmbd	
3724	R	dentary w/ m1	3.55	1.75	1.4	1N 3E 65-70 cmbd	fragment
3725	R	m1	3.15	1.5	1.15	1N 3E 65-70 cmbd	
3726	R	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3727	R	m1	3.3	1.6	0.8	1N 3E 65-70 cmbd	
3728	R	m1	-	-	-	1N 3E 65-70 cmbd	worn, digested
3729	R	m1	-	-	-	1N 3E 65-70 cmbd	fragment
3730	L	m1	3.4	1.75	1.2	1N 3E 65-70 cmbd	
3731	R	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3732	R	m1	2.65	1.25	0.15	1N 3E 65-70 cmbd	
3733	L	m1	3.5	1.55	0.8	1N 3E 65-70 cmbd	
3734	R	m1	3.35	1.6	0.9	1N 3E 65-70 cmbd	
3735	R	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3736	L	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3737	L	m1	-	-	-	1N 3E 65-70 cmbd	digested
3738	L	m1	3.5	1.8	1.55	1N 3E 65-70 cmbd	
3739	R	m1	-	-	-	1N 3E 65-70 cmbd	damaged
3740	R	m1	-	-	-	1N 3E 65-70 cmbd	juvenile
3741	R	m1	-	-	-	1N 3E 65-70 cmbd	fragment
3742	L	m1	-	-	-	1N 3E 65-70 cmbd	worn
3743	R	m1	3.45	1.7	1.5	1N 3E 65-70 cmbd	
3744	R	m1	2.85	1.3	0.3	1N 3E 65-70 cmbd	
3745	R	m1	2.9	1.45	0.7	1N 3E 65-70 cmbd	
3746	R	m1	3.1	1.55	0.95	1N 3E 65-70 cmbd	
3747	R	m1	3.55	1.7	1.55	1N 3E 65-70 cmbd	
3748	R	m1	3.2	1.6	1.4	1N 3E 65-70 cmbd	
3749	L	m1	-	-	-	1N 3E 65-70 cmbd	digested
3750	R	m1	-	-	-	1N 3E 65-70 cmbd	digested
3751	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3752	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3753	L?	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3754	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3755	L	m1	2.85	1.45	0.25	2N 2-3E 65-70 cmbd	
3756	R	m1	2.8	1.3	0.8	2N 2-3E 65-70 cmbd	
3757	L	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3758	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3759	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3760	L	m1	3.25	1.55	1.05	2N 2-3E 65-70 cmbd	
3761	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3762	L	m1	3.05	1.55	0.6	2N 2-3E 65-70 cmbd	
3763	L	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3764	L	m1	3.45	1.6	1.2	2N 2-3E 65-70 cmbd	
3765	L	m1	2.7	1.35	0.25	2N 2-3E 65-70 cmbd	
3766	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3767	L	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3768	R	m1	-	-	-	2N 2-3E 65-70 cmbd	fragment
3769	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3770	R	m1	3.05	1.65	0.85	2N 2-3E 65-70 cmbd	
3771	R	dentary w/ m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile; partial
3772	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3773	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3774	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3775	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3776	L	m1	-	-	-	2N 2-3E 65-70 cmbd	fragment
3777	L	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3778	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3779	R	m1	3.0	1.6	0.75	2N 2-3E 65-70 cmbd	
3780	L	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3781	L	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3782	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3783	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3784	L	m1	3.5	1.7	0.85	2N 2-3E 65-70 cmbd	
3785	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3786	L	m1	2.95	1.55	1.0	2N 2-3E 65-70 cmbd	
3787	L	m1	3.25	1.6	1.4	2N 2-3E 65-70 cmbd	
3788	L	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3789	L	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3790	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3791	R	m1	3.45	1.85	0.3	2N 2-3E 65-70 cmbd	
3792	L	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3793	L	m1	-	-	-	2N 2-3E 65-70 cmbd	fragment
3794	L	m1	2.9	1.45	0.55	2N 2-3E 65-70 cmbd	
3795	R	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged
3796	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3797	L	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3798	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3799	L	m1	3.3	1.6	1.6	2N 2-3E 65-70 cmbd	
3800	R	m1	3.75	1.85	1.65	2N 2-3E 65-70 cmbd	
3801	L	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3802	L	m1	3.7	1.7	1.65	2N 2-3E 65-70 cmbd	
3803	L	m1	3.65	1.85	1.35	2N 2-3E 65-70 cmbd	
3804	R	dentary w/ m1	-	-	-	2N 2-3E 65-70 cmbd	fragment
3805	L	m1	3.3	1.55	0.5	2N 2-3E 65-70 cmbd	
3806	L	m1	3.2	1.5	0.8	2N 2-3E 65-70 cmbd	
3807	R	m1	3.25	1.55	0.35	2N 2-3E 65-70 cmbd	
3808	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested; damaged
3809	R	m1	3.05	1.45	0.3	2N 2-3E 65-70 cmbd	
3810	R	m1	3.65	1.8	1.0	2N 2-3E 65-70 cmbd	
3811	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3812	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3813	L	m1	3.2	1.5	1.15	2N 2-3E 65-70 cmbd	
3814	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3815	R	m1	-	-	-	2N 2-3E 65-70 cmbd	worn
3816	R	m1	-	-	-	2N 2-3E 65-70 cmbd	juvenile
3817	L	m1	3.15	1.45	1.2	2N 2-3E 65-70 cmbd	
3818	L	m1	3.35	1.75	0.9	2N 2-3E 65-70 cmbd	
3819	L	m1	-	-	-	2N 2-3E 65-70 cmbd	damaged; worn
3820	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3821	R	m1	3.15	1.65	0.2	2N 2-3E 65-70 cmbd	
3822	R	m1	2.75	1.5	0.3	2N 2-3E 65-70 cmbd	
3823	R	m1	-	-	-	2N 2-3E 65-70 cmbd	digested
3824	R	m1	2.65	1.35	0.7	2N 2-3E 65-70 cmbd	
829	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
836	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
838	R	m1	3.5	1.8	1.05	1N 2-3E 70-75 cmbd	
840	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
843	L	dentary w/ m1	-	-	-	1N 2-3E 70-75 cmbd	fragment; juvenile
846	R	m1	3.25	1.75	0.55	1N 2-3E 70-75 cmbd	
852	R	m1	3.5	1.7	1.15	1N 2-3E 70-75 cmbd	
854	R	m1	3.9	2.05	1.5	1N 2-3E 70-75 cmbd	
3825	R	m1	2.75	1.4	0.5	1N 2-3E 70-75 cmbd	
3826	R	m1	3.0	1.45	0.9	1N 2-3E 70-75 cmbd	
3827	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3828	L	m1	3.45	1.7	1.25	1N 2-3E 70-75 cmbd	
3829	L	m1	3.65	1.85	0.95	1N 2-3E 70-75 cmbd	
3830	L	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3841	L	m1	3.5	1.9	1.55	1N 2-3E 70-75 cmbd	
3842	R	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3843	L	m1	3.35	1.65	0.35	1N 2-3E 70-75 cmbd	
3844	L	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3845	L	m1	2.95	1.5	1.5	1N 2-3E 70-75 cmbd	
3846	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3847	L	m1	2.8	1.4	0.9	1N 2-3E 70-75 cmbd	
3848	L	m1	2.85	1.4	0.75	1N 2-3E 70-75 cmbd	
3849	R	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3850	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3851	R	m1	3.15	1.45	0.85	1N 2-3E 70-75 cmbd	
3852	R	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3853	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3854	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3855	L	m1	3.5	1.8	0.85	1N 2-3E 70-75 cmbd	
3856	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3857	L	m1	2.95	1.35	0.65	1N 2-3E 70-75 cmbd	
3858	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3859	L	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3860	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3861	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3862	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3863	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3864	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3865	L	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3866	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3867	R	m1	3.05	1.45	0.15	1N 2-3E 70-75 cmbd	
3868	L	m1	2.8	1.35	0.45	1N 2-3E 70-75 cmbd	
3869	L	dentary w/ m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3870	R	dentary w/ i1, m1	-	-	-	1N 2-3E 70-75 cmbd	partial
3871	R	m1	2.9	1.4	0.5	1N 2-3E 70-75 cmbd	
3872	L	m1	3.2	1.65	0.85	1N 2-3E 70-75 cmbd	
3873	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3874	R	m1	-	-	-	1N 2-3E 70-75 cmbd	
3875	R	m1	-	-	-	1N 2-3E 70-75 cmbd	fragment
3876	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3877	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3878	R	m1	3.35	1.6	1.1	1N 2-3E 70-75 cmbd	
3879	L	m1	3.3	1.5	1.3	1N 2-3E 70-75 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3880	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3881	L	m1	3.25	1.65	0.65	1N 2-3E 70-75 cmbd	
3882	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3883	R	m1	3.65	1.85	1.4	1N 2-3E 70-75 cmbd	
3884	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3885	L	m1	3.25	1.5	1.25	1N 2-3E 70-75 cmbd	
3886	L	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3887	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3888	L	m1	2.95	1.5	0.3	1N 2-3E 70-75 cmbd	
3889	L	m1	3.15	1.65	0.9	1N 2-3E 70-75 cmbd	
3890	R	m1	3.1	1.55	0.45	1N 2-3E 70-75 cmbd	
3891	R	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3892	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3893	R	m1	3.8	1.9	1.0	1N 2-3E 70-75 cmbd	
3894	L	m1	3.35	1.75	0.9	1N 2-3E 70-75 cmbd	
3895	L	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3896	L	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3897	R	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3898	R	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3899	L	m1	2.75	1.2	0.7	1N 2-3E 70-75 cmbd	
3900	L	m1	-	-	-	1N 2-3E 70-75 cmbd	worn
3901	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3902	R	m1	2.95	1.45	0.8	1N 2-3E 70-75 cmbd	
3903	L	m1	3.75	1.8	1.6	1N 2-3E 70-75 cmbd	
3904	R	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged
3905	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3906	L	m1	3.65	1.6	1.4	1N 2-3E 70-75 cmbd	
3907	L	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged; digested?
3908	R	m1	2.7	1.4	0.35	1N 2-3E 70-75 cmbd	
3909	R	m1	3.1	1.75	0.45	1N 2-3E 70-75 cmbd	
3910	L	m1	-	-	-	1N 2-3E 70-75 cmbd	damaged; digested
3911	L	m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3912	L	dentary w/ i1, m1	-	-	-	1N 2-3E 70-75 cmbd	juvenile
3913	R	m1	3.55	1.8	0.55	1N 2-3E 70-75 cmbd	
3914	R	m1	3.25	1.6	1.2	1N 2-3E 70-75 cmbd	
3915	R	m1	-	-	-	1N 2-3E 70-75 cmbd	digested
3916	L	m1	2.8	1.5	0.35	1N 2-3E 70-75 cmbd	
3917	L	m1	3.2	1.6	1.2	2N 2-3E 70-75 cmbd	
3918	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3919	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3920	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3921	L	m1	3.4	1.75	1.5	2N 2-3E 70-75 cmbd	
3922	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3923	L	m1	3.55	1.65	1.65	2N 2-3E 70-75 cmbd	
3924	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3925	R	dentary w/ i1, m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3926	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested?
3927	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3928	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3929	L	m1	2.85	1.45	0.45	2N 2-3E 70-75 cmbd	
3930	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3931	L	m1	3.65	1.75	1.05	2N 2-3E 70-75 cmbd	
3932	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3933	R	m1	3.35	1.45	1.15	2N 2-3E 70-75 cmbd	
3934	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3935	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3936	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3937	R	m1	2.9	1.6	0.6	2N 2-3E 70-75 cmbd	
3938	L	m1	3.15	1.55	1.05	2N 2-3E 70-75 cmbd	
3939	R	m1	3.1	1.5	1.2	2N 2-3E 70-75 cmbd	
3940	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3941	R	m1	3.45	1.65	0.55	2N 2-3E 70-75 cmbd	
3942	L	m1	2.5	1.3	0.3	2N 2-3E 70-75 cmbd	
3943	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3944	L	m1	3.65	1.9	-	2N 2-3E 70-75 cmbd	
3945	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3946	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile; digested
3947	L	m1	3.3	1.65	1.1	2N 2-3E 70-75 cmbd	
3948	L	m1	2.9	1.4	0.8	2N 2-3E 70-75 cmbd	
3949	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3950	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3951	L	m1	3.35	1.65	1.25	2N 2-3E 70-75 cmbd	
3952	R	dentary w/ m1	3.05	1.65	0.3	2N 2-3E 70-75 cmbd	fragment
3953	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3954	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3955	R	m1	3.1	1.55	0.65	2N 2-3E 70-75 cmbd	
3956	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3957	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3958	R	m1	3.8	1.85	1.05	2N 2-3E 70-75 cmbd	
3959	L	m1	2.9	1.55	0.15	2N 2-3E 70-75 cmbd	
3960	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3961	L	m1	3.15	1.5	1.95	2N 2-3E 70-75 cmbd	
3962	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
3963	L	m1	-	-	-	2N 2-3E 70-75 cmbd	fragment
3964	L	m1	3.5	1.75	0.95	2N 2-3E 70-75 cmbd	
3965	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3966	L	m1	3.7	1.9	1.25	2N 2-3E 70-75 cmbd	
3967	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3968	L	m1	3.0	1.35	0.55	2N 2-3E 70-75 cmbd	
3969	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3970	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3971	L	m1	-	-	-	2N 2-3E 70-75 cmbd	fragment
3972	L	m1	3.25	1.5	-	2N 2-3E 70-75 cmbd	
3973	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
3974	L	m1	3.5	1.7	1.2	2N 2-3E 70-75 cmbd	
3975	R	m1	3.1	1.55	0.6	2N 2-3E 70-75 cmbd	
3976	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3977	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
3978	R	m1	3.05	1.5	0.65	2N 2-3E 70-75 cmbd	
3979	R	m1	3.45	1.8	0.9	2N 2-3E 70-75 cmbd	
3980	R	m1	3.35	1.7	1.65	2N 2-3E 70-75 cmbd	
3981	L	m1	2.95	1.6	0.3	2N 2-3E 70-75 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
3982	R	m1	2.9	1.5	0.1	2N 2-3E 70-75 cmbd	
3983	L	m1	2.95	1.45	0.5	2N 2-3E 70-75 cmbd	
3984	R	m1	2.85	1.55	0.2	2N 2-3E 70-75 cmbd	
3985	R	m1	3.5	1.8	1.65	2N 2-3E 70-75 cmbd	
3986	R	m1	3.4	1.7	1.25	2N 2-3E 70-75 cmbd	
3987	R	m1	3.65	1.75	1.15	2N 2-3E 70-75 cmbd	
3988	R	m1	2.8	1.5	0.25	2N 2-3E 70-75 cmbd	
3989	R	m1	3.4	1.6	0.95	2N 2-3E 70-75 cmbd	
3990	R	m1	2.75	1.3	0.8	2N 2-3E 70-75 cmbd	
3991	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3992	L	m1	3.55	1.9	1.2	2N 2-3E 70-75 cmbd	
3993	L	m1	3.55	1.75	0.8	2N 2-3E 70-75 cmbd	
3994	L	m1	3.35	1.65	0.85	2N 2-3E 70-75 cmbd	
3995	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3996	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
3997	L	m1	3.75	1.85	1.55	2N 2-3E 70-75 cmbd	
3998	R	m1	3.55	1.85	1.0	2N 2-3E 70-75 cmbd	
3999	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4000	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4001	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4002	R	m1	3.45	1.8	1.0	2N 2-3E 70-75 cmbd	
4003	R	m1	3.6	2.0	1.05	2N 2-3E 70-75 cmbd	
4004	R	m1	3.3	1.7	0.75	2N 2-3E 70-75 cmbd	
4005	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4006	R	m1	3.35	1.75	0.7	2N 2-3E 70-75 cmbd	
4007	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4008	L	m1	3.2	1.55	1.0	2N 2-3E 70-75 cmbd	
4009	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4010	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4011	R	m1	2.8	1.45	0.75	2N 2-3E 70-75 cmbd	
4012	L	m1	3.35	1.6	0.6	2N 2-3E 70-75 cmbd	
4013	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4014	L	m1	3.35	1.75	1.25	2N 2-3E 70-75 cmbd	
4015	L	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4016	R	m1	3.3	1.65	0.15	2N 2-3E 70-75 cmbd	
4017	L	m1	3.4	1.6	0.65	2N 2-3E 70-75 cmbd	
4018	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4019	R	m1	3.4	1.7	0.85	2N 2-3E 70-75 cmbd	
4020	R	m1	3.35	1.65	0.5	2N 2-3E 70-75 cmbd	
4021	L	m1	2.9	1.55	0.5	2N 2-3E 70-75 cmbd	
4022	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
4023	R	m1	3.5	1.65	1.4	2N 2-3E 70-75 cmbd	
4024	?	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4025	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4026	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4027	L	m1	3.5	1.65	1.55	2N 2-3E 70-75 cmbd	
4028	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4029	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4030	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4031	L	m1	3.2	1.65	2.1	2N 2-3E 70-75 cmbd	
4032	R	m1	2.95	1.5	0.5	2N 2-3E 70-75 cmbd	
4033	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4034	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4035	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4036	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4037	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged; digested
4038	L	m1	2.9	1.4	0.6	2N 2-3E 70-75 cmbd	
4039	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4040	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4041	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4042	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4043	R	m1	2.85	1.5	0.6	2N 2-3E 70-75 cmbd	
4044	R	m1	2.95	1.4	0.75	2N 2-3E 70-75 cmbd	
4045	L	m1	3.05	1.55	0.2	2N 2-3E 70-75 cmbd	
4046	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4047	L	m1	3.4	1.7	1.5	2N 2-3E 70-75 cmbd	
4048	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4049	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4050	L	m1	3.55	1.7	1.3	2N 2-3E 70-75 cmbd	
4051	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4052	R	m1	3.45	1.55	1.35	2N 2-3E 70-75 cmbd	
4053	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4054	R	m1	3.6	1.65	1.55	2N 2-3E 70-75 cmbd	
4055	R	m1	3.75	1.95	1.05	2N 2-3E 70-75 cmbd	
4056	L	m1	3.05	1.6	0.6	2N 2-3E 70-75 cmbd	
4057	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
4058	R	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4059	L	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4060	R	m1	3.7	2.0	0.65	2N 2-3E 70-75 cmbd	
4061	L	m1	-	-	-	2N 2-3E 70-75 cmbd	worn
4062	L	m1	3.6	1.85	1.35	2N 2-3E 70-75 cmbd	
4063	R	m1	3.6	1.9	1.55	2N 2-3E 70-75 cmbd	
4064	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4065	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4066	L	m1	2.9	1.5	0.65	2N 2-3E 70-75 cmbd	
4067	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4068	R	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4069	R	m1	3.05	1.55	-	2N 2-3E 70-75cmbd	
4070	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4071	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
4072	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile; digested
4073	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile; digested
4074	L	m1	2.75	1.4	0.7	2N 2-3E 70-75 cmbd	
4075	R	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4076	R	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
4077	R	m1	3.25	1.65	0.45	2N 2-3E 70-75 cmbd	
4078	L	m1	-	-	-	2N 2-3E 70-75 cmbd	digested
4079	L	m1	3.35	1.75	0.6	2N 2-3E 70-75 cmbd	
4080	L	m1	-	-	-	2N 2-3E 70-75 cmbd	damaged
4081	L	m1	-	-	-	2N 2-3E 70-75 cmbd	juvenile
4082	L	m1	2.85	1.4	0.55	2N 2-3E 70-75 cmbd	
4083	L	m1	3.75	1.95	1.05	1N 2-3E 75-80 cmbd	
4084	R	m1	3.3	1.65	1.55	1N 2-3E 75-80 cmbd	
4085	R	n1	-	-	-	1N 2-3E 75-80 cmbd	worn
4086	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4087	R	m1	3.6	1.9	-	1N 2-3E 75-80 cmbd	damaged
4088	L	m1	2.85	1.6	0.3	1N 2-3E 75-80 cmbd	
4089	L	m1	3.2	-	-	1N 2-3E 75-80 cmbd	damaged
4090	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged
4091	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4092	R	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4093	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4094	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged
4095	R	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4096	R	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4097	R	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4098	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged
4099	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4100	R	m1	3.45	1.65	0.4	1N 2-3E 75-80 cmbd	
4101	L	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4102	R	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4103	R	m1	3.3	1.8	0.65	1N 2-3E 75-80 cmbd	
4104	R	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4105	L	m1	2.95	1.4	0.3	1N 2-3E 75-80 cmbd	
4106	R	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4107	L	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4108	R	m1	3.6	1.9	1.95	1N 2-3E 75-80 cmbd	
4109	L	m1	3.3	1.65	0.55	1N 2-3E 75-80 cmbd	
4110	L	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4111	R	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4112	L	m1	3.7	1.8	0.9	1N 2-3E 75-80 cmbd	
4113	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4114	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged
4115	R	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4116	R	m1	3.5	1.9	-	1N 2-3E 75-80 cmbd	worn
4117	L	m1	3.7	1.9	1.15	1N 2-3E 75-80 cmbd	
4118	R	m1	3.4	1.65	1.25	1N 2-3E 75-80 cmbd	
4119	L	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4120	R	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4121	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4122	L	m1	3.35	1.6	1.05	1N 2-3E 75-80 cmbd	
4123	L	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4124	L	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4125	L	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4126	R	m1	3.4	1.7	-	1N 2-3E 75-80 cmbd	damaged
4127	R	m1	3.35	1.85	1.35	1N 2-3E 75-80 cmbd	
4128	R	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4129	L	m1	-	-	-	1N 2-3E 75-80 cmbd	digested
4130	L	m1	3.55	1.8	1.25	1N 2-3E 75-80 cmbd	
4131	R	m1	-	-	-	1N 2-3E 75-80 cmbd	juvenile
4132	L	m1	3.05	1.55	1.0	1N 2-3E 75-80 cmbd	
4133	L	m1	-	-	-	1N 2-3E 75-80 cmbd	damaged
4134	R	m1	-	-	-	1N 2-3E 75-80 cmbd	worn
4135	R	m1	3.65	1.9	0.95	1N 2-3E 75-80 cmbd	
4136	R	dentary w/ m1-m2	-	-	-	1N 2-3E 75-80 cmbd	damaged
4137	L	m1	3.75	1.85	0.85	2N 2-3E 75-80 cmbd	
4138	L	m1	3.3	1.45	1.1	2N 2-3E 75-80 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4139	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4140	L	m1	3.35	1.6	1.0	2N 2-3E 75-80 cmbd	
4141	R	dentary w/ m1	-	-	-	2N 2-3E 75-80 cmbd	fragment; damaged
4142	L	m1	3.3	1.65	1.3	2N 2-3E 75-80 cmbd	
4143	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4144	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4145	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4146	R	dentary w/ m1	3.45	1.55	0.75	2N 2-3E 75-80 cmbd	fragment
4147	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested; worn
4148	R	m1	3.2	1.5	0.7	2N 2-3E 75-80 cmbd	
4149	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4150	L	m1	3.1	1.5	1.4	2N 2-3E 75-80 cmbd	
4151	R	m1	3.25	1.6	0.75	2N 2-3E 75-80 cmbd	
4152	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4153	R	m1	2.95	1.55	0.35	2N 2-3E 75-80 cmbd	
4154	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4155	L	m1	3.9	1.8	1.55	2N 2-3E 75-80 cmbd	
4156	R	m1	3.4	1.65	1.5	2N 2-3E 75-80 cmbd	
4157	R	m1	3.0	1.65	1.05	2N 2-3E 75-80 cmbd	
4158	L	m1	3.2	1.5	0.8	2N 2-3E 75-80 cmbd	
4159	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4160	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4161	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4162	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4163	R	m1	3.4	1.75	0.8	2N 2-3E 75-80 cmbd	
4164	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4165	R	m1	3.45	1.8	0.95	2N 2-3E 75-80 cmbd	
4166	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4167	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4168	R	m1	3.55	1.75	1.4	2N 2-3E 75-80 cmbd	
4169	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4170	L	m1	2.9	1.6	0.8	2N 2-3E 75-80 cmbd	
4171	R	m1	2.7	1.3	0.5	2N 2-3E 75-80 cmbd	
4172	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4173	L	m1	2.8	1.4	0.55	2N 2-3E 75-80 cmbd	
4174	R	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4175	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4176	L	m1	3.0	1.55	1.1	2N 2-3E 75-80 cmbd	
4177	L	m1	3.55	1.85	1.05	2N 2-3E 75-80 cmbd	
4178	R	m1	3.55	1.7	1.25	2N 2-3E 75-80 cmbd	
4179	R	m1	3.3	1.75	0.3	2N 2-3E 75-80 cmbd	
4180	R	m1	3.25	1.5	0.8	2N 2-3E 75-80 cmbd	
4181	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4182	L	m1	2.9	1.5	0.35	2N 2-3E 75-80 cmbd	
4183	L	m1	3.0	1.55	0.75	2N 2-3E 75-80 cmbd	
4184	R	m1	3.1	1.4	0.75	2N 2-3E 75-80 cmbd	
4185	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4186	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4187	R	m1	3.8	2.0	0.95	2N 2-3E 75-80 cmbd	
4188	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4189	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4190	L	m1	3.05	1.55	0.3	2N 2-3E 75-80 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4191	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile; damaged
4192	R	m1	3.9	1.95	1.25	2N 2-3E 75-80 cmbd	
4193	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4194	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4195	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged; digested
4196	R	m1	3.7	1.9	0.8	2N 2-3E 75-80 cmbd	
4197	R	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4198	R	m1	3.5	1.7	1.0	2N 2-3E 75-80 cmbd	
4199	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4200	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4201	R	m1	2.95	1.6	0.25	2N 2-3E 75-80 cmbd	
4202	L	m1	2.95	1.55	0.1	2N 2-3E 75-80 cmbd	
4203	R	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4204	R	m1	2.9	1.55	0.35	2N 2-3E 75-80 cmbd	
4205	R	m1	3.0	1.5	0.8	2N 2-3E 75-80 cmbd	
4206	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4207	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4208	L	m1	3.1	1.5	0.35	2N 2-3E 75-80 cmbd	
4209	R	m1	3.15	1.5	0.65	2N 2-3E 75-80 cmbd	
4210	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4211	L	m1	2.85	1.5	1.0	2N 2-3E 75-80 cmbd	
4212	L	m1	3.55	1.75	1.6	2N 2-3E 75-80 cmbd	
4213	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4214	L	m1	3.15	1.65	0.35	2N 2-3E 75-80 cmbd	
4215	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4216	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4217	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4218	R	m1	3.2	1.6	0.85	2N 2-3E 75-80 cmbd	
4219	R	dentary w/ m1	-	-	-	2N 2-3E 75-80 cmbd	fragment; damaged
4220	R	m1	3.65	1.9	1.45	2N 2-3E 75-80 cmbd	
4221	L	m1	3.4	1.7	0.5	2N 2-3E 75-80 cmbd	
4222	R	dentary w/ m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4223	R	m1	3.15	1.85	0.75	2N 2-3E 75-80 cmbd	
4224	L	m1	3.55	1.6	1.1	2N 2-3E 75-80 cmbd	
4225	L	m1	3.35	1.8	1.0	2N 2-3E 75-80 cmbd	
4226	R	m1	3.45	1.7	0.65	2N 2-3E 75-80 cmbd	
4227	R	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4228	R	m1	3.45	1.9	1.5	2N 2-3E 75-80 cmbd	
4229	L	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4230	L	dentary w/ m1	2.9	1.65	0.25	2N 2-3E 75-80 cmbd	fragment
4231	R	m1	2.9	1.4	0.45	2N 2-3E 75-80 cmbd	
4232	L	m1	3.05	1.5	0.5	2N 2-3E 75-80 cmbd	
4233	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4234	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4235	R	m1	3.7	2.0	1.0	2N 2-3E 75-80 cmbd	
4236	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4237	L	dentary w/ m1-m2	-	-	-	2N 2-3E 75-80 cmbd	fragment; worn
4238	R	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4239	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4240	L	m1	3.15	1.65	0.8	2N 2-3E 75-80 cmbd	
4241	L	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4242	R	m1	3.35	1.8	1.25	2N 2-3E 75-80 cmbd	
4243	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4244	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4245	R	m1	-	-	-	2N 2-3E 75-80 cmbd	damaged
4246	L	m1	-	-	-	2N 2-3E 75-80 cmbd	worn
4247	L	m1	-	-	-	2N 2-3E 75-80 cmbd	fragment
4248	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4249	R	m1	3.35	1.9	1.0	2N 2-3E 75-80 cmbd	
4250	L	m1	3.45	1.75	1.25	2N 2-3E 75-80 cmbd	
4251	R	m1	3.6	1.8	1.15	2N 2-3E 75-80 cmbd	
4252	L	dentary w/ m1	-	-	-	2N 2-3E 75-80 cmbd	fragment; worn
4253	R	m1	3.65	1.85	0.6	2N 2-3E 75-80 cmbd	
4254	L	m1	3.5	1.65	1.2	2N 2-3E 75-80 cmbd	
4255	L	m1	3.55	1.8	1.2	2N 2-3E 75-80 cmbd	
4256	R	m1	3.25	1.55	0.6	2N 2-3E 75-80 cmbd	
4257	L	m1	3.35	1.6	0.85	2N 2-3E 75-80 cmbd	
4258	R	dentary w/ i1, m1	3.3	1.6	1.45	2N 2-3E 75-80 cmbd	
4259	L	m1	3.25	1.6	0.95	2N 2-3E 75-80 cmbd	
4260	R	m1	-	-	-	2N 2-3E 75-80 cmbd	juvenile
4261	L	m1	-	-	-	2N 2-3E 75-80 cmbd	digested
4262	L	m1	-	-	-	1N 2-3E 80-85 cmbd	fragment
4263	R	m1	-	-	-	1N 2-3E 80-85 cmbd	digested
4264	R	m1	-	-	-	1N 2-3E 80-85 cmbd	worn
4265	L	m1	3.35	1.55	1.1	1N 2-3E 80-85 cmbd	
4266	L	m1	-	-	-	1N 2-3E 80-85 cmbd	worn
4267	R	m1	3.0	1.7	0.8	1N 2-3E 80-85 cmbd	
4268	L	m1	-	-	-	1N 2-3E 80-85 cmbd	damaged
4269	R	m1	-	-	-	1N 2-3E 80-85 cmbd	digested
4270	R	m1	3.3	1.7	1.15	1N 2-3E 80-85 cmbd	
4271	L	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4272	R	m1	2.9	1.35	0.7	2N 2-3E 80-85 cmbd	
4273	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4274	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4275	R	m1	3.6	1.95	0.85	2N 2-3E 80-85 cmbd	
4276	R	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4277	L	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4278	L	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4279	L	m1	3.0	1.6	0.85	2N 2-3E 80-85 cmbd	
4280	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4281	L	m1	2.75	1.5	0.45	2N 2-3E 80-85 cmbd	
4282	R	m1	3.45	1.8	0.95	2N 2-3E 80-85 cmbd	
4283	R	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4284	R	m1	3.1	1.45	1.1	2N 2-3E 80-85 cmbd	
4285	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4286	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4287	R	m1	3.15	1.65	0.65	2N 2-3E 80-85 cmbd	
4288	L	m1	3.1	1.55	0.5	2N 2-3E 80-85 cmbd	
4289	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4290	R	m1	3.3	1.65	0.8	2N 2-3E 80-85 cmbd	
4291	L	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4292	R	m1	3.8	1.9	-	2N 2-3E 80-85 cmbd	damaged
4293	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4294	L	m1	3.45	1.6	1.25	2N 2-3E 80-85 cmbd	
4295	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4296	L	m1	3.45	1.75	0.75	2N 2-3E 80-85 cmbd	
4297	L	m1	3.5	2.0	1.05	2N 2-3E 80-85 cmbd	
4298	R	m1	3.55	1.95	1.7	2N 2-3E 80-85 cmbd	
4299	L	m1	3.0	1.5	0.4	2N 2-3E 80-85 cmbd	
4300	L	m1	3.65	1.9	1.4	2N 2-3E 80-85 cmbd	
4301	L	m1	2.85	1.5	0.45	2N 2-3E 80-85 cmbd	
4302	L	m1	3.85	1.85	1.2	2N 2-3E 80-85 cmbd	
4303	R	dentary w/ m1	-	-	-	2N 2-3E 80-85 cmbd	fragment; damaged
4304	R	m1	3.1	1.65	0.8	2N 2-3E 80-85 cmbd	
4305	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4306	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4307	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4308	L	m1	3.1	1.6	1.1	2N 2-3E 80-85 cmbd	
4309	L	m1	3.5	1.85	1.5	2N 2-3E 80-85 cmbd	
4310	R	m1	-	-	-	2N 2-3E 80-85 cmbd	fragment
4311	R	m1	3.05	1.5	0.5	2N 2-3E 80-85 cmbd	
4312	L	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4313	L	dentary w/ m1	-	-	-	2N 2-3E 80-85 cmbd	fragment; worn
4314	R	m1	3.6	1.85	0.55	2N 2-3E 80-85 cmbd	
4315	L	m1	3.3	1.6	0.45	2N 2-3E 80-85 cmbd	
4316	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4317	R	m1	3.0	1.5	1.25	2N 2-3E 80-85 cmbd	
4318	L	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4319	R	m1	2.65	1.3	0.3	2N 2-3E 80-85 cmbd	
4320	L	dentary w/ m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4321	L	m1	3.2	1.5	0.7	2N 2-3E 80-85 cmbd	
4322	R	m1	3.05	1.4	0.45	2N 2-3E 80-85 cmbd	
4323	R	m1	2.9	1.45	0.65	2N 2-3E 80-85 cmbd	
4324	L	m1	3.25	1.6	0.55	2N 2-3E 80-85 cmbd	
4325	L	dentary w/ m1	-	-	-	2N 2-3E 80-85 cmbd	fragment; juvenile
4326	R	m1	2.9	1.6	0.5	2N 2-3E 80-85 cmbd	
4327	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4328	R	m1	3.25	1.65	0.5	2N 2-3E 80-85 cmbd	
4329	L	m1	3.05	1.55	1.3	2N 2-3E 80-85 cmbd	
4330	R	m1	3.05	1.65	0.45	2N 2-3E 80-85 cmbd	
4331	L	m1	3.05	1.55	0.55	2N 2-3E 80-85 cmbd	
4332	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4333	L	m1	3.75	1.75	1.55	2N 2-3E 80-85 cmbd	
4334	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4335	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4336	L	m1	3.5	1.7	1.1	2N 2-3E 80-85 cmbd	
4337	R	m1	2.8	1.4	0.2	2N 2-3E 80-85 cmbd	
4338	L	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4339	R	m1	3.55	1.65	1.05	2N 2-3E 80-85 cmbd	
4340	R	m1	3.25	1.75	0.8	2N 2-3E 80-85 cmbd	
4341	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4342	L	m1	2.85	1.5	0.65	2N 2-3E 80-85 cmbd	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4343	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4344	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4345	R	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4346	R	m1	3.05	1.65	1.15	2N 2-3E 80-85 cmbd	
4347	R	m1	3.15	1.65	1.1	2N 2-3E 80-85 cmbd	
4348	L	m1	4.1	2.0	1.15	2N 2-3E 80-85 cmbd	
4349	R	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4350	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4351	L	m1	3.6	1.7	1.65	2N 2-3E 80-85 cmbd	
4352	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4353	L	m1	2.9	1.4	0.7	2N 2-3E 80-85 cmbd	
4354	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4355	L	m1	2.85	1.55	0.3	2N 2-3E 80-85 cmbd	
4356	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4357	R	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4358	R	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4359	L	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4360	R	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4361	R	dentary w/ m1-m2	-	-	-	2N 2-3E 80-85 cmbd	fragment; digested
4362	L	m1	-	-	-	2N 2-3E 80-85 cmbd	fragment
4363	R	m1	3.25	1.6	1.1	2N 2-3E 80-85 cmbd	
4364	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4365	R	m1	3.15	1.6	1.2	2N 2-3E 80-85 cmbd	
4366	R	m1	3.65	1.65	0.85	2N 2-3E 80-85 cmbd	
4367	L	m1	3.15	1.75	1.0	2N 2-3E 80-85 cmbd	
4368	L	m1	-	-	-	2N 2-3E 80-85 cmbd	digested
4369	L	m1	-	-	-	2N 2-3E 80-85 cmbd	fragment
4370	L	m1	3.3	1.75	0.3	2N 2-3E 80-85 cmbd	
4371	L	m1	-	-	-	2N 2-3E 80-85 cmbd	damaged
4372	L	m1	3.15	1.6	0.55	2N 2-3E 80-85 cmbd	
4373	L	m1	3.35	1.75	1.1	2N 2-3E 80-85 cmbd	
4374	R	m1	3.55	1.9	-	2N 2-3E 80-85 cmbd	damaged
4375	L	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4376	R	m1	3.0	1.55	0.5	2N 2-3E 80-85 cmbd	
4377	R	m1	2.95	1.55	0.4	2N 2-3E 80-85 cmbd	
4378	R	m1	3.6	1.85	1.05	2N 2-3E 80-85 cmbd	
4379	R	m1	3.4	1.8	-	2N 2-3E 80-85 cmbd	worn
4380	R	m1	3.0	1.5	0.9	2N 2-3E 80-85 cmbd	
4381	L	m1	-	-	-	2N 2-3E 80-85 cmbd	worn
4382	R	m1	-	-	-	2N 2-3E 80-85 cmbd	juvenile
4383	L	m1	-	-	-	1N 2-3E 85-90 cmbd	damaged
4384	L	m1	3.4	1.65	0.6	1N 2-3E 85-90 cmbd	
4385	L	m1	3.2	1.45	0.9	1N 2-3E 85-90 cmbd	
4386	R	m1	2.95	1.5	0.6	1N 2-3E 85-90 cmbd	
4387	L	m1	-	-	-	1N 2-3E 85-90 cmbd	digested
4388	L	m1	3.65	1.9	1.5	1N 2-3E 85-90 cmbd	
4389	L	m1	3.25	1.6	1.95	1N 2-3E 85-90 cmbd	
4390	L	m1	-	-	-	1N 2-3E 85-90 cmbd	juvenile
4391	R	m1	-	-	-	1N 2-3E 85-90 cmbd	digested
4392	L	m1	-	-	-	1N 2-3E 85-90 cmbd	damaged
4393	R	m1	-	-	-	1N 2-3E 85-90 cmbd	digested
4394	R	m1	-	-	-	1N 2-3E 85-90 cmbd	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4395	L	m1	2.95	1.55	0.15	1N 2-3E 85-90 cmbd	
4396	L	m1	-	-	-	1N 2-3E 85-90 cmbd	digested
4397	R	m1	3.35	1.75	1.15	2N 2-3E 85-90 cmbd	
4398	R	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4399	R	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4400	R	m1	-	-	-	2N 2-3E 85-90 cmbd	juvenile
4401	L	m1	-	-	-	2N 2-3E 85-90 cmbd	juvenile
4402	L	m1	-	-	-	2N 2-3E 85-90 cmbd	worn
4403	L	dentary w/ m1	2.8	1.55	0.15	2N 2-3E 85-90 cmbd	fragment
4404	R	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4405	L	dentary w/ m1	-	-	-	2N 2-3E 85-90 cmbd	fragment; damaged
4406	L	m1	3.6	1.7	1.25	2N 2-3E 85-90 cmbd	
4407	L	m1	3.05	1.5	0.4	2N 2-3E 85-90 cmbd	
4408	R	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4409	R	m1	3.25	1.7	0.8	2N 2-3E 85-90 cmbd	
4410	L	m1	3.55	1.7	1.3	2N 2-3E 85-90 cmbd	
4411	L	m1	3.05	1.6	0.65	2N 2-3E 85-90 cmbd	
4412	L	m1	-	-	-	2N 2-3E 85-90 cmbd	juvenile
4413	L	m1	3.15	1.6	0.9	2N 2-3E 85-90 cmbd	
4414	R	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4415	L	m1	-	-	-	2N 2-3E 85-90 cmbd	digested
4416	L	m1	2.8	1.45	0.5	2N 2-3E 85-90 cmbd	
4417	L	m1	3.65	1.95	1.15	2N 2-3E 85-90 cmbd & below	
4418	R	m1	-	-	-	2N 2-3E 85-90 cmbd & below	digested
4419	L	m1	-	-	-	2N 2-3E 85-90 cmbd & below	worn
4420	R	m1	3.4	1.4	1.5	2N 2-3E 85-90 cmbd & below	
4421	L	m1	-	-	-	2N 2-3E 85-90 cmbd & below	juvenile
4422	R	m1	3.1	1.6	0.1	2N 2-3E 85-90 cmbd & below	
4423	R	m1	3.4	1.65	1.55	2N 2-3E 85-90 cmbd & below	
4424	R	m1	-	-	-	2N 2-3E 85-90 cmbd & below	juvenile
4425	L	m1	-	-	-	2N 2-3E 85-90 cmbd & below	digested?
4426	L	m1	3.15	1.65	0.65	2N 2-3E 85-90 cmbd & below	
4427	R	dentary w/ m1	-	-	-	2N 2-3E 85-90 cmbd & below	fragment; worn
1087	L	dentary w/ m1	2.75	1.55	0.35	2N 3E 85-110; below flowstone	fragment
1093	L	m1	-	-	-	2N 3E 85-110; below flowstone	digested
1111	R	m1	-	-	-	2N 3E 85-110; below flowstone	fragment
4428	L	m1	-	-	-	2N 3E 85-110; below flowstone	juvenile
4429	R	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	digested
4430	L	m1	3.65	1.95	1.2	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4431	L	m1	3.15	1.65	0.25	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4432	R	m1	3.0	1.65	0.45	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4433	L	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	juvenile

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4434	R	m1	2.9	1.5	0.55	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4435	R	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	juvenile
4436	L	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	damaged
4437	L	m1	3.35	1.65	0.85	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4438	R	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	digested
4439	R	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	worn
4440	L	m1	2.85	1.5	0.45	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	
4441	L	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	digested
4442	R	m1	-	-	-	1-2N 2-3E 87-102 cmbd; below pedasteled rocks	juvenile; digested
4443	R	m1	3.75	1.9	1.6	2N 2-3E 90-95 cmbd	
4444	L	m1	3.1	-	-	2N 2-3E 90-95 cmbd	digested
4445	L	m1	-	-	-	2N 2-3E 90-95 cmbd	damaged
4446	R	m1	2.95	1.5	0.15	2N 2-3E 90-95 cmbd	
4447	L	m1	-	-	-	2N 2-3E 90-95 cmbd	worn
4448	R	m1	-	-	-	2N 2-3E 90-95 cmbd	damaged
4449	R	m1	-	-	-	2N 2-3E 90-95 cmbd	damaged
4450	L	m1	-	-	-	2N 2-3E 90-95 cmbd	fragment
4451	R	m1	-	-	-	2N 2-3E 90-95 cmbd	worn
4452	R	m1	-	-	-	2N 2-3E 90-95 cmbd	juvenile
4453	L	m1	2.9	1.45	0.3	2N 2-3E 90-95 cmbd	
4454	R	m1	2.8	1.5	0.15	2N 2-3E 90-95 cmbd	
4455	R	m1	-	-	-	2N 2-3E 90-95 cmbd	juvenile
4456	R	m1	-	-	-	2N 2-3E 90-95 cmbd	damaged
4457	R	m1	2.8	1.4	0.5	2N 2-3E 90-95 cmbd	
4458	L	m1	-	-	-	2N 2-3E 90-95 cmbd	juvenile
4459	R	m1	3.45	1.65	1.1	2N 2-3E 90-95 cmbd	
4460	L	m1	-	-	-	2N 2-3E 90-95 cmbd	damaged
4461	L	dentary w/ m1	-	-	-	2N 2-3E 90-95 cmbd	fragment; damaged
4462	R	m1	3.3	1.65	1.1	2N 2-3E 90-95 cmbd	
4463	R	m1	-	-	-	2N 2-3E 90-95 cmbd	worn; digested
4464	R	m1	-	-	-	2N 2-3E 90-95 cmbd	fragment
4465	L	m1	-	-	-	2N 2-3E 90-95 cmbd	digested
4466	L	m1	-	-	-	2N 2-3E 90-95 cmbd	digested
4467	L	m1	-	-	-	2N 2-3E 90-95 cmbd	juvenile
4468	L	m1	3.55	1.75	1.0	2N 2-3E 90-95 cmbd	
4469	L	m1	-	-	-	2N 2-3E 90-95 cmbd	worn
4470	L	m1	-	-	-	2N 2-3E 90-95 cmbd	juvenile
4471	R	m1	-	-	-	2N 2-3E 90-95 cmbd	worn; digested
4472	L	m1	3.6	1.8	0.9	1N 2-3E 90 cmbd & below	
4473	R	m1	-	-	-	1N 2-3E 90 cmbd & below	juvenile
4474	L	m1	-	-	-	1N 2-3E 90 cmbd & below	juvenile; digested
4475	L	m1	3.35	1.6	0.6	1N 2-3E 90 cmbd & below	

Appendix 9 continued.

Specimen No.	Side	Element	*l*	*w*	*h*-dt	Provenience	Comments
4476	L	m1	-	-	-	1N 2-3E 90 cmbd & below	juvenile
4477	L	m1	3.55	1.75	1.1	1N 2-3E 90 cmbd & below	
4478	R	m1	-	-	-	1N 2-3E 90 cmbd & below	worn
4479	L	m1	-	-	-	1N 2-3E 90 cmbd & below	fragment
4480	L	m1	-	-	-	1N 2-3E 90 cmbd & below	damaged
4481	L	m1	2.85	1.55	0.45	2N 2-3E 95-102 cmbd	
4482	R	m1	-	-	-	2N 2-3E 95-102 cmbd	worn
4483	R	m1	3.45	1.7	1.2	2N 2-3E 95-102 cmbd	
4484	L	dentary w/ m1	3.0	1.55	0.85	2N 2-3E 95-102 cmbd	fragment
4485	R	m1	2.9	1.6	0.35	2N 3E 100-105 cmbd	
4486	R	m1	-	-	-	2N 3E 100-105 cmbd	damaged
4487	L	m1	-	-	-	2N 3E 100-105 cmbd	juvenile
4488	L	m1	-	-	-	2N 3E 100-105 cmbd	worn
4489	R	m1	-	-	-	2N 3E 100-105 cmbd	juvenile; digested
4490	L	m1	2.8	1.45	0.75	2N 3E 100-105 cmbd	
4491	L	m1	-	-	-	2N 3E 100-105 cmbd	worn
4492	R	m1	3.5	1.6	0.7	2N 3E 100-105 cmbd	
4493	L	m1	-	-	-	2N 3E 100-105 cmbd	juvenile
4494	L	m1	3.05	1.4	0.9	2N 3E 100-105 cmbd	
4495	R	m1	-	-	-	2N 3E 100-105 cmbd	digested
4496	R	m1	-	-	-	2N 3E 100-105 cmbd	damaged
4497	R	m1	-	-	-	2N 3E 100-105 cmbd	digested
4498	L	m1	3.0	1.35	1.1	2N 3E 100-105 cmbd	
4499	R	m1	3.7	1.8	1.0	2N 3E 100-105 cmbd	
4500	R	m1	3.0	1.45	0.6	2N 3E 100-105 cmbd	
4501	R	m1	3.6	1.6	1.4	2N 3E 100-105 cmbd	
4502	R	m1	3.1	1.6	1.0	2N 3E 100-105 cmbd	
4503	L	m1	-	-	-	2N 3E 100-105 cmbd	juvenile
4504	L	dentary w/ m1	-	-	-	2N 3E 100-105 cmbd	worn
4505	R	m1	-	-	-	2N 3E 105-110 cmbd	juvenile
4506	R	dentary w/ i1, m1-m3	3.6	1.8	1.15	2N 2-3E 60-65 cmbd	
4507	L	dentary w/ m1	3.25	1.55	-	1N 2E 55-60 cmbd	fragment
4508	R	dentary w/ m1-m3	3.15	1.7	1.1	1N 3E 65-70 cmbd	
4509	L	dentary w/ i1, m1-m3	3.9	1.95	1.1	2N 2-3E 45-60 cmbd	
4510	R	dentary w/ i1, m1-m2	-	-	-	2N 2-3E 70-75 cmbd	worn
4511	L	m1	3.25	1.5	1.35	1N 2E 45-50 cmbd	
4512	R	m1	3.2	1.7	0.75	1N 2E 45-50 cmbd	
4513	L	m1	-	-	-	1N 2E 45-50 cmbd	worn
4514	L	m1	-	-	-	1N 2E 45-50 cmbd	juvenile

Appendix 10. NISP, MNI, and Relative Abundance Data for Arvicoline Rodents from Cathedral Cave.

Data is listed by excavation level/taxon.

Excavation Level/Taxon	NISP	MNI	Relative Abundance (NISP)	Relative Abundance (MNI)
25-30 cmbd				
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	0	0	0	0
Microtus meadensis	0	0	0	0
Microtus paroperarius	0	0	0	0
Microtus sp.	0	0	0	0
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys gryci	0	0	0	0
Phenacomys sp.	0	0	0	0
Totals	0	0		
30-35 cmbd				
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	1	1	0.17	0.20
Microtus meadensis	0	0	0	0
Microtus paroperarius	2	1	0.33	0.20
Microtus sp.	1	1	0.17	0.20
Mictomys meltoni or *M. kansasensis*	1	1	0.17	0.20
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	1	1	0.17	0.20
Phenacomys sp.	0	0	0	0
Totals	6	5		

Appendix 10 continued.

35-40 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	8	6	0.47	0.50
Microtus meadensis	0	0	0	0
Microtus paroperarius	1	1	0.06	0.08
Microtus sp.	8	5	0.47	0.42
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	0	0	0	0
Phenacomys sp.	0	0	0	0
Totals	17	12		
40-45 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	13	9	0.46	0.47
Microtus meadensis	1	1	0.04	0.05
Microtus paroperarius	2	1	0.07	0.05
Microtus sp.	12	8	0.43	0.42
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	0	0	0	0
Phenacomys sp.	0	0	0	0
Totals	28	19		

Appendix 10 continued.

Cemented Level	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	2	2	0.06	0.08
Lemmiscus curtatus	13	9	0.38	0.36
Microtus meadensis	1	1	0.03	0.04
Microtus paroperarius	2	2	0.06	0.08
Microtus sp.	12	8	0.35	0.32
Mictomys meltoni or *M. kansasensis*	1	1	0.03	0.04
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	0	0	0	0
Phenacomys sp.	3	2	0.09	0.08
Totals	34	25		
45-60 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	6	3	0.03	0.03
Lemmiscus curtatus	79	40	0.41	0.36
Microtus meadensis	4	2	0.02	0.02
Microtus paroperarius	13	8	0.07	0.07
Microtus sp.	79	47	0.41	0.43
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	1	1	0.01	0.01
Ondatra sp.	1	1	0.01	0.01
Phenacomys cf. *P. gryci*	9	6	0.05	0.05
Phenacomys sp.	3	2	0.02	0.02
Totals	195	110		

Appendix 10 continued.

60-65 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	2	1	0.02	0.02
Lemmiscus curtatus	53	33	0.58	0.60
Microtus meadensis	1	1	0.01	0.02
Microtus paroperarius	5	3	0.05	0.05
Microtus sp.	27	14	0.29	0.25
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	4	3	0.04	0.05
Phenacomys sp.	0	0	0	0
Totals	92	55		
65-70 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	3	3	0.04	0.07
Lemmiscus curtatus	38	20	0.50	0.47
Microtus meadensis	1	1	0.01	0.02
Microtus paroperarius	3	2	0.04	0.05
Microtus sp.	29	16	0.38	0.37
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	2	1	0.03	0.02
Phenacomys sp.	0	0	0	0
Totals	76	43		

Appendix 10 continued.

70-75 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	1	1	0.01	0.02
Lemmiscus curtatus	20	11	0.24	0.22
Microtus meadensis	4	4	0.05	0.08
Microtus paroperarius	9	6	0.11	0.12
Microtus sp.	38	21	0.46	0.43
Mictomys meltoni or *M. kansasensis*	3	2	0.04	0.04
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	7	4	0.09	0.08
Phenacomys sp.	0	0	0	0
Totals	82	49		
75-80 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	27	18	0.38	0.41
Microtus meadensis	1	1	0.01	0.02
Microtus paroperarius	5	3	0.07	0.07
Microtus sp.	36	19	0.50	0.43
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	3	3	0.04	0.07
Phenacomys sp.	0	0	0	0
Totals	72	44		

Appendix 10 continued.

80-85 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	19	12	0.44	0.48
Microtus meadensis	3	2	0.07	0.08
Microtus paroperarius	4	2	0.09	0.08
Microtus sp.	16	8	0.37	0.32
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	1	1	0.02	0.04
Phenacomys sp.	0	0	0	0
Totals	43	25		
85-90 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	1	1	0.05	0.07
Lemmiscus curtatus	14	9	0.67	0.64
Microtus meadensis	0	0	0	0
Microtus paroperarius	3	2	0.14	0.14
Microtus sp.	2	1	0.10	0.07
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	1	1	0.05	0.07
Phenacomys sp.	0	0	0	0
Totals	21	14		

Appendix 10 continued.

90-95 cmbd	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	5	3	0.36	0.27
Microtus meadensis	3	3	0.21	0.27
Microtus paroperarius	1	1	0.07	0.09
Microtus sp.	5	4	0.36	0.36
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	0	0	0	0
Phenacomys sp.	0	0	0	0
Totals	14	11		
95 cmbd and below	NISP	MNI	NISP RA	MNI RA
Allophaiomys pliocaenicus	0	0	0	0
Lemmiscus curtatus	10	6	0.71	0.67
Microtus meadensis	0	0	0	0
Microtus paroperarius	0	0	0	0
Microtus sp.	4	3	0.29	0.33
Mictomys meltoni or *M. kansasensis*	0	0	0	0
Mictomys sp.	0	0	0	0
Ondatra sp.	0	0	0	0
Phenacomys cf. *P. gryci*	0	0	0	0
Phenacomys sp.	0	0	0	0
Totals	14	9		

Appendix 11. NISP, MNI, and Relative Abundance Data for Lagomorphs from Cathedral Cave.

Data is listed by excavation level/taxon.

Excavation Level/ Taxon	NISP	MNI	Relative Abundance (NISP)	Relative Abundance (MNI)
25-30 cmbd				
Aztlanolagus agilis	0	0	0	0
Brachylagus idahoensis	1	1	1.00	1.0
Brachylagus coloradoensis	0	0	0	0
Ochotona sp.	0	0	0	0
Sylvilagus or *Lepus* sp.	0	0	0	0
Total	1	1		
30-35 cmbd				
Aztlanolagus agilis	0	0	0	0
Brachylagus idahoensis	0	0	0	0
Brachylagus coloradoensis	0	0	0	0
Ochotona sp.	1	1	0.50	0.50
Sylvilagus or *Lepus* sp.	1	1	0.50	0.50
Total	2	3		
35-40 cmbd				
Aztlanolagus agilis	0	0	0	0
Brachylagus idahoensis	0	0	0	0
Brachylagus coloradoensis	0	0	0	0
Ochotona sp.	1	1	1.00	1.0
Sylvilagus or *Lepus* sp.	0	0	0	0
Total	1	1		
40-45 cmbd				
Aztlanolagus agilis	2	1	0.20	0.17
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	5	3	0.50	0.50
Sylvilagus or *Lepus* sp.	3	2	0.30	0.33
Total	10	6		

Appendix 11 continued.

Excavation Level/ Taxon	NISP	MNI	Relative Abundance (NISP)	Relative Abundance (MNI)
Cemented Level				
Aztlanolagus agilis	1	1	0.13	0.20
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	5	3	0.63	0.60
Sylvilagus or *Lepus* sp.	2	1	0.25	0.20
Total	8	5		
45-60 cmbd				
Aztlanolagus agilis	4	2	0.12	0.11
Brachylagus idahoensis	1	1	0.03	0.05
Brachylagus coloradoensis	0	0	0	0
Ochotona sp.	15	9	0.44	0.47
Sylvilagus or *Lepus* sp.	14	7	0.41	0.37
Total	34	19		
60-65 cmbd				
Aztlanolagus agilis	3	2	0.20	0.25
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	8	4	0.53	0.50
Sylvilagus or *Lepus* sp.	4	2	0.27	0.25
Total	15	8		
65-70 cmbd				
Aztlanolagus agilis	5	3	0.28	0.25
Brachylagus idahoensis	0	0	0	0
Brachylagus coloradoensis	1	1	0.06	0.08
Ochotona sp.	8	5	0.44	0.42
Sylvilagus or *Lepus* sp.	4	3	0.22	0.25
Total	18	12		

Appendix 11 continued.

Excavation Level/ Taxon	NISP	MNI	Relative Abundance (NISP)	Relative Abundance (MNI)
70-75 cmbd				
Aztlanolagus agilis	2	2	0.14	0.18
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	3	2	0.21	0.18
Sylvilagus or *Lepus* sp.	9	7	0.64	0.64
Total	14	11		
75-80 cmbd				
Aztlanolagus agilis	2	2	0.13	0.17
Brachylagus idahoensis	1	1	0.06	0.08
Brachylagus coloradoensis	0	0	0	0
Ochotona sp.	9	7	0.56	0.58
Sylvilagus or *Lepus* sp.	4	2	0.25	0.17
Total	16	12		
80-85 cmbd				
Aztlanolagus agilis	1	1	0.08	0.10
Brachylagus idahoensis	0	0	0	0
Brachylagus coloradoensis	1	1	0.08	0.10
Ochotona sp.	4	4	0.31	0.40
Sylvilagus or *Lepus* sp.	7	4	0.54	0.40
Total	13	10		
85-90 cmbd				
Aztlanolagus agilis	1	1	0.13	0.20
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	7	4	0.88	0.80
Sylvilagus or *Lepus* sp.	0	0	0	0.00
Total	8	5		

Appendix 11 continued.

Excavation Level/ Taxon	NISP	MNI	Relative Abundance (NISP)	Relative Abundance (MNI)
90-95 cmbd				
Aztlanolagus agilis	2	2	0.29	0.33
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	3	2	0.43	0.33
Sylvilagus or *Lepus* sp.	2	2	0.29	0.33
Total	7	6		
95 cmbd and below				
Aztlanolagus agilis				
Brachylagus idahoensis	0	0	0	0.00
Brachylagus coloradoensis	0	0	0	0.00
Ochotona sp.	0	0	0	0.00
Sylvilagus or *Lepus* sp.	5	4	0.83	0.80
Aztlanolagus agilis	1	1	0.17	0.20
Total	6	5		

Appendix 12. Sliding Scale Relative Abundance Data (NISP) for Arvicoline Rodents from Cathedral Cave.

Data is listed by excavation level/taxon.

Level 1-2 (25-30 cmbd, 30-35 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	0	0
Lemmiscus curtatus	1	0.17
Microtus meadensis	0	0
Microtus paroperarius	2	0.33
Microtus sp.	1	0.17
Mictomys meltoni or *M. kansasensis*	1	0.17
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	1	0.17
Phenacomys sp.	0	0
Total	6	
Level 2-3 (30-35 cmbd, 35-40 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	0	0
Lemmiscus curtatus	9	0.39
Microtus meadensis	0	0
Microtus paroperarius	3	0.13
Microtus sp.	9	0.39
Mictomys meltoni or *M. kansasensis*	1	0.04
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	1	0.04
Phenacomys sp.	0	0
Total	23	

Appendix 12 continued.

Level 3-4 (35-40 cmbd, 40-45 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	0	0
Lemmiscus curtatus	21	0.47
Microtus meadensis	1	0.02
Microtus paroperarius	3	0.07
Microtus sp.	20	0.44
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	0	0
Phenacomys sp.	0	0
Total	45	
Level 4-5 (40-45 cmbd, cemented level)	NISP	NISP RA
Allophaiomys pliocaenicus	2	0.03
Lemmiscus curtatus	26	0.42
Microtus meadensis	2	0.03
Microtus paroperarius	4	0.06
Microtus sp.	24	0.39
Mictomys meltoni or *M. kansasensis*	1	0.02
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	0	0
Phenacomys sp.	3	0.05
Total	62	
Level 5-6 (cemented level, 45-60 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	8	0.03
Lemmiscus curtatus	92	0.4
Microtus meadensis	5	0.02
Microtus paroperarius	15	0.07
Microtus sp.	91	0.4
Mictomys meltoni or *M. kansasensis*	1	0
Mictomys sp.	1	0
Ondatra sp.	1	0
Phenacomys cf *P. gryci*	9	0.04
Phenacomys sp.	6	0.03
Total	229	

Appendix 12 continued.

Levels 6-7 (45-60 cmbd, 60-65 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	8	0.03
Lemmiscus curtatus	132	0.46
Microtus meadensis	5	0.02
Microtus paroperarius	18	0.06
Microtus sp.	106	0.37
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	1	0
Ondatra sp.	1	0
Phenacomys cf *P. gryci*	13	0.05
Phenacomys sp.	3	0.01
Total	287	
Levels 7-8 (60-65 cmbd, 65-70 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	5	0.03
Lemmiscus curtatus	91	0.54
Microtus meadensis	2	0.01
Microtus paroperarius	8	0.05
Microtus sp.	56	0.33
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	6	0.04
Phenacomys sp.	0	0
Total	168	
Level 8-9 (65-70 cmbd, 70-75 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	4	0.03
Lemmiscus curtatus	58	0.37
Microtus meadensis	5	0.03
Microtus paroperarius	12	0.08
Microtus sp.	67	0.42
Mictomys meltoni or *M. kansasensis*	3	0.02
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	9	0.06
Phenacomys sp.	0	0
Total	158	

Appendix 12 continued.

Level 9-10 (70-75 cmbd, 75-80 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	1	0
Lemmiscus curtatus	47	0.31
Microtus meadensis	5	0.03
Microtus paroperarius	14	0.09
Microtus sp.	74	0.48
Mictomys meltoni or *M. kansasensis*	3	0.02
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	10	0.06
Phenacomys sp.	0	0
Total	154	
Level 10-11 (75-80 cmbd, 80-85 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	0	0
Lemmiscus curtatus	46	0.4
Microtus meadensis	4	0.03
Microtus paroperarius	9	0.08
Microtus sp.	52	0.45
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	4	0.03
Phenacomys sp.	0	0
Total	115	
Level 11-12 (80-85 cmbd, 85-90 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	1	0.02
Lemmiscus curtatus	33	0.52
Microtus meadensis	3	0.05
Microtus paroperarius	7	0.11
Microtus sp.	18	0.28
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	2	0.03
Phenacomys sp.	0	0
Total	64	

Appendix 12 continued.

Level 12-13 (85-90 cmbd, 90-95 cmbd)	NISP	NISP RA
Allophaiomys pliocaenicus	1	0.03
Lemmiscus curtatus	19	0.54
Microtus meadensis	3	0.09
Microtus paroperarius	4	0.11
Microtus sp.	7	0.2
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	1	0.03
Phenacomys sp.	0	0
Total	35	
Level 13-14 (90-95 cmbd, 95 cmbd and below)	NISP	NISP RA
Allophaiomys pliocaenicus	0	0
Lemmiscus curtatus	15	0.54
Microtus meadensis	3	0.11
Microtus paroperarius	1	0.04
Microtus sp.	9	0.32
Mictomys meltoni or *M. kansasensis*	0	0
Mictomys sp.	0	0
Ondatra sp.	0	0
Phenacomys cf *P. gryci*	0	0
Phenacomys sp.	0	0
Total	28	

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